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EEnvest

Risk reduction for Building Energy Efficiency investments

Replication potential report

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n. 833112

ABSTRACT

This report D6.3 is concerned with the replication potential of the EEnvest platform for energy efficiency investments in the Residential sector. After a specific market analysis, it was found that pending today the final vote on the new EPBD (Energy Performance Building Directive) Recast, the core of energy efficiency Residential market potential will be driven by this EPBD Recast. This market is confined to multi-store buildings with no heat insulation that will be obliged to conform to the MEPS (Minimum Energy Performance Standards) imposed on all buildings in Europe. In this market, deep renovation of the multi-story apartment buildings will lead to investments, of the order of 40.000 to 200.000 € which is a reasonable budget for investing in additional risk analysis studies in a cost-effective way, as those supported by the EEnvest platform.

Moreover, the development of risk probability distribution curves for performance gaps and equipment or envelope damages are examined in detail. Such probability distributions are developed for a wide range of energy saving applications in both the building envelop and the technical systems. For this development, and employing:

- Statistical analysis of historical data;
- Non-statistical specifications of distribution values;

the following type of databases were developed, as shown in the following table for all elements of Table 2.4:

ENERGY PERFORMANCE GAP - DATABASE

	Low		Medium		High	
	Prob. %	Impact	Prob. %	Impact	Prob. %	Impact
Air infiltration						
Thermal bridge						
...						

It was found that these so developed databases for risk probability curves do not distinguish fundamentally for building elements in the Commercial and Residential sectors. Therefore, the EEnvest platform can equally handle or is capable of equally handling applications in the Residential sector. However, the minimum Budget of an energy efficiency project is set to 50.000 € and above, which justifies a Risk Assessment Study through EEnvest application, the cost of which for this application is estimate between 3000 to 5000 € for a relatively experienced EEnvest platform user.

Finally, the tool of the Project Quality Self-Assessment, based on the Desktop Due Diligence Questionnaire, was separately examined. It was found that this tool is of primary importance to accompany the Risk Assessment EEnvest methodology since it focuses on other aspects of project development such as Monitoring and Verification (M&V) aspects or some other aspects of Design and Construction (D&C) like acceptance testing, which constitute prerequisites to a highly organized and integrated project. However, due to the extensive requirements in terms of additional engineering and associated studies, only projects with a budget above 100.000 € will be encouraged to submit a DDDQ. Projects below that figure will be asked to answer only a part of DDDQ, whereas for projects below 50.000 it is left to building owners or contractors to decide whether to submit a DDDQ analysis.

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List of abbreviations and acronyms

This list must be as short as possible as abbreviations and acronyms hamper an easy understanding of deliverables by reviewers.

KPI	Key Performance Indicators
O&M	Operation & Maintenance
D&C	Design & Construction
ECM	Energy Conservation Measure
DDDQ	Desktop Due Diligence Questionnaire
M&V	Monitoring & Verification
EEM	Energy Efficiency Measures
EPBD	Energy Performance of Buildings Directive
MEP	Minimum Energy Performance
ZEB	Zero Energy Buildings
EPC	Energy Performance Certificate
ESM	Energy Savings Measure
ES	Energy Savings
EED	Energy Efficiency Directive
HVAC	Heating, Ventilation and Air-Conditioning
HDD	Heating Degree Days
CDD	Cooling Degree Days
IPMVP	International Performance Monitoring and Verification Protocols
RF	Reconciliation Factor

1 INTRODUCTION

1.1 SCOPE AND OBJECTIVES

1.1.1 Added value of EEnvest for building owners, contractors/engineers and banks

EEnvest aims at supporting and accelerating investors´ decision-making process by translating the building's energy efficiency technical requirements into economic indicators. These indicators are in turn used to evaluate financial risks associated with deep renovation investment and to include non-energy benefits in evaluation models. EEnvest will allow the financial sector to match the EE investments demand and offer commercial office buildings across Europe. EEnvest will increase financiers', investors', owners' and users' mutual trust, by identifying, quantifying and mitigating technical risks associated with the specific type of investment technologies, as well as by reducing the cost of credit for lenders through targeted risk reduction actions. EEnvest has developed effective evaluation methods for the technical/financial risks assessment by categorizing a number of major technical risks and quantifying their impact on total investment risk. And all this is performed on a user-friendly platform.

The question that naturally arises and is explored in the report is whether the EEnvest Evaluation methodology can be replicated to buildings in the residential sector which contains the vast majority of the buildings in Europe rising to 70% or higher.

Therefore, this report identifies necessary requirements to replicate the EEnvest approach outside of the reference market that we are targeting during the project, to set the foreground for ease of replicability after project ends, in other geographic and building use markets, with a specific focus on residential buildings. Once target requirements are identified, a gap analysis will be performed to benchmark the current status of the EEnvest framework with respect to residential buildings and clearly identify actions to be undertaken in the short term to eliminate shortcomings and foster extensive replicability of the approach after the project end.

The objective here is to:

- raise the level of confidence of Residential building owners in investing in the energy efficiency market and
- raise the confidence of contractors and financiers in Energy Saving Projects (ESP), by providing a robust and standard methodology for a fast screening of ESPs in the residential sector and therefore increase the accelerated penetration of ESPs in the Residential Sector.

1.1.2 Technical and financial risks covered by EEnvest

A technical risk is defined as "an exposure to loss arising from activities such as design and engineering, manufacturing, technological processes and test procedures". Related to the building sector, a technical risk is the probability or threat of equipment damage or performance deviation from the design value or any other negative occurrence (thermal bridge, air or water infiltration …) at the building components (architectural elements of the building envelope, HVAC systems or RES systems), caused by a variety of reasons (calculation or installation, or management errors) in the various phases of the construction process (design, construction, operation). Technical risks are identified as possible performance deviations or failures in design, construction or operation phase. However, it is assumed that no technical risk associated with a certain intervention, i.e., window or boiler replacement, if they have procurement or construction warranties from the contractor.

This lack of information base is particularly relevant in the case of existing buildings that need renovation, due to the difficulty in determining the exact performance and commercial value impact of energy efficiency actions using a standardized approach. **Such uncertainty** is deemed to undermine investor confidence and willingness to employ capital in the energy efficiency market, slowing down EU decarbonization (related but not limited to the existing building stock).

The main objective of EEnvest project is to secure investors´ trust in energy efficiency actions for existing buildings, mainstreaming energy efficiency financing, thanks to a structured framework for **technical and financial risk** evaluation. EEnvest includes also non-energy related benefits in a solid and comprehensive knowledge-based investment evaluation method, through the conversion of technical building features into investor-ready financial parameters, using a **framework for standardization** and benchmarking of energy efficiency-related investments.

Identification of **technical risks** is associated with investments in energy efficiency for commercial and residential buildings, with details relevant to the different phases of project development: design, financing, execution, procurement, operation & maintenance.

Technical risks are deemed to arise due to purely technical issues, such as components delayed delivery, and faulty installation on the damaged component; conversely, they can also be attributed to procurement-related issues that are worth investigating. Identified failures and related causes will be clustered according to their expected impact on building energy performance, operation and maintenance (O&M) costs and commercial attractiveness (= value) of the building.

Technical and **financial risk** evaluation model: integration of technical parameters into financial model, model functioning description, and **definition of KPIs** (Key Performance Indicators) for renovation investments.

In this “replication” report, we explore the question whether risk models developed here are also applicable and appropriate for the residential sector in both views:

- Technical and financial feasibility in terms of applicability of the risk models
- Person-hour effort required to implement EEnvest risk models in a cost-effective manner in small scale investments

1.1.3 Multi-benefit approach

The benefits of energy efficiency investments go far beyond energy savings. Multiple-Benefits are benefits that occur in addition to energy savings and should be considered in the investment decision-making process.

The Multi-benefit approach developed in EEnvest is to provide building owners/investors with a clear and jargon-free explanation of the state-of-the-art on non-energy benefit such as environmental benefits (air pollution, CO2 reduction), socio-economic benefits (jobs, energy supply security), individual (comfort, health) and company related benefits (employee productivity).

Although not all of the above parameters are relevant to the Residential sector, the inclusion of non-energy benefits in the business cases may be very effective in accelerating positive decision making for energy efficiency projects.

1.2 RESIDENTIAL MARKET FOR REPLICATION OF EENVEST

1.2.1 Target requirements of Residential market and gaps

In order to assess the replication potential, it is necessary to identify what are the main requirements to replicate the EEnvest approach, outside of the reference market that we are targeting during the project, to set the foreground for ease of replicability after the project ends, in other geographic and building use markets, with a specific focus on residential buildings. Once target requirements are identified, a gap analysis will be performed to benchmark the current status of EEnvest framework with respect to residential buildings and clearly identify actions to be undertaken in the short term to eliminate shortcomings and foster extensive replicability of the approach after the project ends.

1.2.2 Gap analysis

The gap analysis concentrates on the technical risks arising during the implementation of an Energy Conservation Measure (ECM) in terms of performance gaps from its design value due to faulty behavior or damage to equipment or structural elements installed in the building envelope (thermal bridges, water infiltration, etc.).

In the financial performance risks, gap or damage analysis concentrates on:

- probability distributions for Gas Energy price Gap, Electricity Energy price Gap, and Damage are examined, and on the data requirements;
- likely Extra data inputs required by the user other than the standard input data of EEnvest in order to generate the probability distributions mentioned above.

The question here to explore is whether data requirements developed for ECM (Energy Conservation Measures) applications in the commercial sector are also valid for residential ECMs applications.

1.2.3 Action planning

The gap analysis identified above to check current status of EEnvest framework with respect to residential buildings, leads to the identification of actions to be undertaken in the short run to eliminate shortcomings and foster extensive replicability of the approach after project end. Also, action planning is developed for long term action and after the completion of the project.

1.2.4 Project quality Self-Assessment (PQSA) methodology

In the course of development and implementation of the above methodology and risk models, additional requirements emerged, to encourage Building owners and/or independent contractors and investors, to invest in the energy efficiency market, taking into account other important parameters, that characterize the quality and feasibility of a proposed Energy Conservation Measure (ECM), on the basis of standard criteria of the Financial Community to assess feasibility and financial performance of an ESM project.

On the basis of this concept, a Project quality Self-Assessment (PQSA) methodology was developed in EEnvest and was implemented by the development of a Desktop Due Diligence Questionnaire (DDDQ) for the commercial Office building market (DDDQ-O), which is structured along with six themes that strike a balance between Design and Commissioning (D&C) techniques, already supported in EEnvest, and Monitoring and Verification (M&V) techniques during the operation phase of a project.

THEME 1: Design of an ECM and energy saving calculations (16 questions)

THEME 2: Implementation of an ECM (= Energy Conservation Measure) (16 questions)

THEME 3: Maintenance and Operation of the energy efficiency Assets (9 questions)

THEME 4: Monitoring of the energy efficiency assets and their energy consumption (7 questions)

THEME 5. Measurement and Verification of the energy savings (6 questions)

THEME 6. Communication with awareness and training of users and/or occupants (7 questions)

The building owner, besides the energy calculations performed to implement the risk assessment methodology, is called upon by EEnvest as an option to complete and submit the DDDQ, which is not straightforward to do, since it takes much more than to fill out this questionnaire, for the following reasons:

a) Low grades in DDDQ will avert building owners to perform risk analysis with EEnvest, despite the fact that DDDQ is treated separately from the main core risk analysis of EEnvest.

b) In order to receive a decent DDDQ grade, will have to spent additional money and effort in order to perform an energy audit by a certified auditor, additional engineering studies to determine commissioning, monitoring, operation and maintenance procedures.

c) Such additional costs and efforts are not required by EPBD and the energy performance certificate (EPC), certainly they are not cost-effective in low budget energy saving projects (i.e boiler replacement or external insulation).

d) Therefore, although the DDDQ analysis is not mandatory to perform in EEnvest risk analysis, it is estimated that DDDQ analysis will be cost-optimal for projects with budgets larger than 100.000 € (plus VAT). For budgets less than that, a short version of DDDQ is suggested, in order to capture some essential engineering aspects of the project.

e) The same cut-off limit of 50K was conservatively estimated and for the EEnvest risk analysis (gap and damage analysis) itself.

   With the above cut-off budgetary limits, the risk analysis becomes cost effective, by avoiding project genuine risks and high-risk premiums, minimizing insurance costs and customer dissatisfaction.

f) With the above cut-off limits EEnvest is expected to penetrate significantly in the energy efficiency market, obtaining progressively the status of a highly reliable tool to minimize risks and uncertainties and minimizing risk premiums.

DDDQ certainly will drive the budget of a project at higher levels since the same structure of DDDQ alone dictates the need for additional spending in seeking higher grade points in this self-assessment tool. Such additional costs of engineering services include:

- performing an energy audit, including the development of one or more energy baselines for the various energy uses (electricity, gas, etc);
- performing basic engineering studies for all proposed energy saving interventions;
- performing basic engineering study for project commissioning and project maintenance;
- development of verification and measurement protocols for each suggested intervention.

These services are all required by PSAT, and unless you have all these in your portfolio, you run the risk of getting a very low DDDQ grade, averting EEnvest platform users in participating in EEnvest PSAT analysis. DDDQ service cost are estimated to rise between 7 and 15%, the higher number corresponding to small budget projects with no energy audit in their portfolio.

Thus, the question that naturally arises here is whether the cost-effectiveness of such DDDQ induced additional spending for small scale investments in the Residential Sector.

2 REVIEW OF REPLICABILITY OF EENVEST RISK MODELS TO THE RESIDENTIAL SECTOR

2.1 THE ENERGY EFFICIENCY MARKETS IN THE RESIDENTIAL SECTOR

2.1.1 General

In order to provide answers for the questions raised in the above paragraphs, it is necessary to obtain a good understanding as to how the energy efficiency market is going to evolve in the Residential Sector of Europe.

Over the last 10 years, the Energy Performance Certificates have been established in the building and housing sectors of all member states after the EPBD (Energy Performance of Buildings Directive) first emerged as EPBD/2002/91/EU. It is now recognized that this directive as well as the new version of it emerged as EPBD/2010/31, did not affect much the real estate renovation market and therefore EPCs (Energy Performance Certificates) have had a minor influence in this market.

The Residential sector includes the vast majority of all buildings in the building sector and therefore the replication potential of EEnvest platform in this sector is of paramount importance to achieve significant penetration of this platform to the building sector.

It is now decided by the Commission that EPBD directive is the main vehicle to promote energy efficiency in all building sectors and therefore the Commission has developed a new draft to recast EPBD, which now includes Minimum Energy Performance Standards (MEPS) and CO2 elimination targets, summarized as follows:

- 55% cut of CO2 emissions from the Building Sector in Europe by 2030
- Eliminate completely CO2 emissions from the Building Sector by 2050
- Promote Near Zero Energy Buildings (NZEB) by 2030 (~ A EPC class)
- Zero Energy Buildings (ZEB) by 2050

2.1.2 The Recast EPBD requirements

Most of the European buildings belong in classes D, E, F and G. i.e., the worst energy classes according to the recast EPBD.

The draft proposal of the Recast EPBD suggest requiring member states to ensure that all existing buildings, owned by public bodies or non-residential buildings, shall satisfy the **Minimum energy performance standards (MEPS)** as follows: F as a minimum EPC Class by 2027 and E as a minimum EPC Class by 2030. These deadlines should be extended to 2030 and 2033 respectively for the Residential buildings.

Furthermore, member states could be asked to establish specific timelines for the above buildings to achieve higher energy performance classes by 2030, 2040 and 2050, in line with the pathway for transforming the national building stock into zero-emission buildings. Consequently, it is expected that most member states will require higher EPC classes than the corresponding classes E and F of all buildings by 2030 and 2033.

The analysis of the new Residential Energy Efficiency Market, evolving in all Europe, is presented in Annex A, where it is concluded that EPBD recast will be the dominant factor in promoting Energy Saving Measures (ESM) in the Residential market in Europe. It is expected that member states will require all Residential buildings to reach EPC class D or even C as a MEP requirement.

This means that to jump from EPC Class E to EPC Class C, ESMs are required with a total energy savings about 44,6% whereas to jump from EPC Class F to EPC Class C, energy savings of about 58,4% should be achieved, irrespective of the Climatic Zone.

ES to C	Climatic Zones [DegreeDays (°)]					Average energy savings
EPC Jump	**A (702)**	**B (947)**	**C (1687)**	**D (2537)**	**E (3085)**	
D → C	25,4%	25,4%	25,4%	25,4%	24,5%	25,2%
E → C	44,3%	44,3%	44,3%	44,3%	45,6%	44,6%
F → C	58,5%	58,5%	58,5%	58,5%	58,0%	58,4%
G → C	69,0%	69,0%	69,0%	69,0%	68,6%	68,9%

Table A-10: Typical Energy Savings (ES) required to Jump to EPC Class C.

2.1.3 Typical EEnvest applications in the Residential sector

In Annex B, typical ESMs are examined to achieve energy savings of the order of 43,5%, ESM implementation costs and associated simple payback periods of investment. This approximately corresponds to investment required to bring a residential apartment house from EPC Class E to Class C with a total energy savings requirement of 44,6% (Table A-10). Three generic ESMs are examined.

- Building heat insulation of roof and external walls;
- Ventilation heat recovery by 85%;
- Boiler replacement with a new condensing boiler.

On the basis of this examination, it is concluded that EPC class upgrade from E to C, requires an investment of 12.500 to 15.000 € and has a payback of 5 to 6 years. For lower initial EPC classes (F, G) the investment requirements to reach Class C, are expected to range from 16.000 € up to 20.000 € and payback periods of 6 to 9 years.

Therefore, and on the basis of the analysis of Annex B, it is concluded that corresponding upgrades for multistory Residential building from F/G EPC Class to C Class would require investments of:

- multi-story buildings with 3 apartments: 48.000 to 60.000 €;
- multi-story buildings with 10 apartments: 160.000 to 200.000 €.

As a conclusion it is noted that EMS in Residential Sector driven by EPBD Recast, can be of significant size, that may justify the additional costs in the engineering studies required by EEnvest platform implementation and corresponding costs for PSAT analysis.

2.2 THE RECAST EPBD AND EED INDUCED MARKET POTENTIAL

2.2.1 General

In this report, two kinds of energy efficiency markets are distinguished:

a) Market 1 based on Minimum Energy Performance Standards (MEPS) introduced into the new Draft EPBD proposal that may or may not be cost effective

b) Market 2 that are purely based on cost-effectiveness, which are expected to be marginal against the regulated markets of EPBD (Market 1). However, even if a building project belongs to the regulated market, it could still benefit from EEnvest risk analysis by minimizing interest and insurance premiums and accelerated decision-making process. On the other hand, financial institutions and insurance industry is expected to progressively acquire increased awareness to the importance of risk analysis and EEnvest use, in order to cash it into their core business.

2.2.2 Conclusions for the EPBD driven market in the Residential Sector (Market 1)

On the basis of the above findings, a rough estimate of the total market potential of the First Stage of EPBD to reach C Class all over Europe up to 2033, can be derived as follows:

As stated in Recital (21) of Recast EPBD proposal, "The necessary decarbonization of the Union building stock requires energy renovation at a large scale: almost 75% of that building stock is inefficient according to current building standards, and 85-95% of the buildings that exist today will still be standing in 2050"

A similar statement is made in Recital (4) of the new Recast EED (Energy Efficiency Directive): "75% of the Union´s building stock has a poor energy performance".

In Greece there is approximately 2 million residential houses in D class of lower. Assuming an average renovation cost of 15.000 per house, then the total renovation budget up to 2033 is approximately 30 billion euros and on an annual basis 2,7 billion Euros.

Based on the above recitals and stretching the above figure on a European Basis, on the basis of population figures (447 million for EU and 10,4 million for Greece), then the total budget up to 2033 is 1,3 trillion euros and 118 billion euros annually.

2.2.3 Cost-effective and Multi-benefit European market potential (Market 2)

Despite the Recast EPBD driven market potential, a relatively smaller market potential is expected to be created due to pure market driven economics such as:

- Cost -effectiveness of energy efficiency investments;
- Multi-benefit drives including:
    - Real Estate property value upgrade (both for sale and for rent);
    - Healthy and ventilated internal environment of buildings, minimizing suspended dust and VOCs (Volatile Organic Carbon), by introducing heat recovery ventilation;
    - Highly comfortable temperature and moisture during heating and cooling period, by upgrading HVAC systems (Heating, Ventilation and Air Conditioning) and automation controls;
    - Minimizing internally external noise and comfort conditions near the windows by installing super insulated windows.

This economics driven market is distinguished from the above mentioned regulated and EBPD driven Market 1, although the majority of interventions in the EPBD driven, regulated Market 1, are also cost-effective.

Therefore, as the recast EPBD is promoting building renovation, the Cost-effective /Multi-benefit driven Market 2 potential is expected to grow in parallel.

Up to 2033, this energy efficiency Market 2 is not expected to generate significant business in the Residential sector since all partners in energy efficiency Services will face limitations in staff development. training and organization, due to the expected explosion of the EPBD driven market which is expected for a country like Greece states to reach a figure of 30 billion euros or more up to 2033 in the next eleven years.

However, at the opposite side, the Recast Energy Efficiency Directive (EED) is expected to generate certain market for Cost-Effective energy savings applications in the Residential sector as explained in the next paragraph.

Anyhow and beyond 2033, the energy efficiency services are expected to be ready to offer these more advanced services for Cost-effective/Multi-benefit market which is expect to cover the more advanced EPBD driven demand for these services.

Consequently, these two markets, driven by the EPBD and the Economic/Multi-benefit/EED are expected to grow in parallel up to 2033, with the EPBD market being the dominant one.

2.2.4 The Recast EED induced market potential (Market 3)

In 14.7.2021, the proposal for a Directive on Energy Efficiency (recast) was issued by COM (2021) 558 final 2021/0203 (COD). In December 2018, a new 2030 Union headline energy efficiency target of at least 32,5% (compared to projected energy use in .2030) was included in Recital (6) of this Recast Directive.

The main concept of this Recast Directive revolves around the concept of Cost-Effective Energy Savings which are defined in Article 2 as follows:

Article 2 - Definitions (7): 'energy savings' means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalization for external conditions that affect energy consumption.

This definition is kept the same from the previous edition of EED 2012/27/EC and revolves around the concept of "normalization" which is usually performed through the concept of the so-called energy baseline, as defined and explained in ISO EN Standard 50001.

Companies in the energy sector (gas and electricity generation, transmission and distribution) will probably be obliged to develop energy saving programs for their customers, promoting annual savings in their energy consumption by 1,5% up to 2031. Obviously, this obligation includes also the Residential Sector but is not expected to generate much income for energy service companies there, due to the fact that energy sector companies are expected to fulfill this obligation by promoting typical energy efficiency applications in the Residential sector such as lighting, and equipment replacement and maintenance.

Article 11 imposes obligations about energy audits and energy management systems for all companies that consume more than 10 TJ and 100 TJ of energy respectively.

The threshold of 100TJ corresponds to 27,8 million kWh. With a load factor 50%, the general installed energy capacity for facilities exceeding this level of energy use for all forms of energy is estimated as follows:

27.800.000 kWh/ (8760 hours/year * 50%) = 6350 kW

Therefore, the 100TJ correspond to 6350 kW installed capacity and the 10 TJ to 635 kW capacity.

Consequently, in both cases, due to the high installed energy capacity criteria, Residential sector buildings do not match these requirements.

2.3 CONCLUSIONS

From the above on the effects of EED induced energy efficiency market potential, it is concluded that this EED induced potential is rather narrow in comparison of the EPBD Recast market potential which amounts up to 2 to 3 trillion euros up to 2033 in Europe, as discussed in paragraph 2.2 The basic market potential for cost-effective energy saving applications does exist for the buildings in the Tertiary sector.

However, some cost-effective market potential (of Market 2) still remains in the Residential sector, purely based on economic grounds, not requiring for government subsidies and state grants.

Therefore, the conclusions of paragraph 2.2.1 are still valid and the main emphasis in the Residential sector is to upgrade of EPC Class for residential buildings, without completely ignoring the Cost-effective and Multi-benefit European market potential.

On the basis of these findings, we distinguish four markets for EEnvest replication in the Residential sector:

Market 1.L: Large scale EPC upgrading applications (≥50.000€)

Market 1.S: Small Scale EPC upgrading applications (<50.000€)

Market 2.L: Large scale energy saving cost-effective applications (≥ 50.000€)

Market 2.S: Small scale energy saving cost-effective applications (<50.000€)

Markets 2.L and 2.S include also the EED typed induced market 3 with purely cost-effective energy saving objectives and not simply to upgrade EPC class. The detailed characteristics of the above four market segments are discussed in more detail in Chapter 3.

2.4 EEnvest risk models Risk models for energy gap and damage analysis

EEnvest addresses risk by explicitly representing uncertainty in energy budgeting and investment analysis. Probability distributions are central to the concept of risk and risk tolerance, and their development and application provide the primary quantitative vehicle used in risk management analysis

Risk Definition: The numerical probability of a negative financial outcome.

Risk Tolerance Definition: The maximum acceptable probability of a negative financial outcome.

The application of probability distributions in EEnvest is handled with Monte Carlo software developed in this project. The objective here is to provide the conceptual background necessary to understand the process and feel confident using software that performs the processes described here.

A useful definition of risk is the numerical probability of a negative financial outcome. More formally, an energy budget risk is the probability (or likelihood) that energy costs will exceed some euro amount, and energy-efficiency investment risk is the risk that the return on the investment will fall short of a target return.

Probability or likelihood is measured from zero to one with the value zero indicating that the event will never occur and one indicating that it will occur with certainty. Probabilities are also measured as percentages ranging from zero to 100 percent. A probability of 25 percent means that there is a one-in-four chance that the event will occur.

The risk definition then suggests the definition of risk tolerance: the maximum acceptable probability of a negative financial outcome. An energy efficiency investment is too risky if the probability of achieving *less than* the required internal rate of return on the investment is greater than the organization's risk tolerance of say, 5 percent. Similarly, the organization is at risk if the probability is more than 5 percent that next year's energy costs will exceed the energy budget by more than the energy budget contingency of, say $10,000.

2.4.1 Risk models required

Risk management analysis requires that each variable that helps determine energy costs or investment return and is subject to any significant degree of uncertainty must be represented by a distribution of outcomes. The methodology for estimating and synthesizing probability curves follows the corresponding methodology presented in "*Energy Budgets at Risk (EBaR)* "*A Risk Management Approach to Energy Purchase and Efficiency Choices*" by Jerry Jackson, (EbaR) [1] which applies two primary approaches to estimating these distributions including:

- statistical analysis of historical data;
- non-statistical specifications of distribution values.

Figure 2.1 is a simplified schematic of the EEnvest Monte Carlo process. Weather, performance and energy price are all subject to uncertainty and represented with a probability distribution. This schematic reflects three input distributions; however, an actual EEnvest analysis applies one distributional representation for each variable subject to uncertainty.

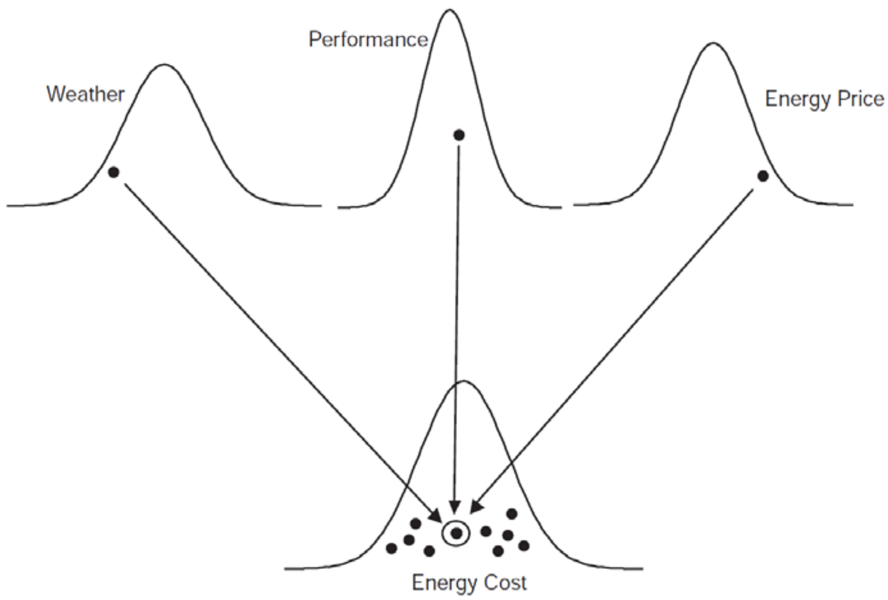


Figure 2.1 Simplified EBaR Monte Carlo Analysis Schematic

A random number generator (RNG) is used to develop random draws from each individual distribution, the inputs are processed to determine the energy cost associated with these values of each variable and the results are stored in the output distribution of energy costs. The process continues until the output distribution is completely synthesized and defined. A Monte Carlo run of the EBaR system with one million draws from the input distributions can be completed within a half minute on most computers. Monte Carlo analysis is the analytical workhorse of EBaR, extracting information from diverse input probability distributions and providing a distribution of outputs and their probability of occurrence.

The probability distribution development process is using any combination of the following inputs:

- historical data series;
- most likely values;
- extreme values;
- other user outcome-probability specifications.

For example, the probability distribution function (for window damage) is determined by the following four regions: Zero impact (NULL hypothesis with 97% probability), 30.900 € additional investment with 1,2% probability, 72.100 additional cost with 1,2% probability and finally 144.200 additional cost with 0,6% probability.

WINDOW¤			DAMAGE¤							
			Investment·cost·(€)·(calculated·on·window·cost)¤							
			NULL¤		LOW¤		MID¤		HIGH¤	
			impact¤	prob¤	impact¤	prob¤	impact¤	prob¤	impact¤	prob¤
°¤	¤	°¤	€¤	%¤	·€·¤	%¤	·€·¤	%¤	·€·¤	%¤
Single· window¤	AIR· INFILTRATION¤	Window· frame¤	0,00¤	97,00%¤	30.900·€·¤	1,20%¤	72.100·€·¤	1,20%¤	144.200·€·¤	0,60%¤

Table 2.1: Example distribution function of window damage due to air Filtration.

Using Monte Carlo techniques with random number generation, the detailed probability distribution is constructed by repeating 10.000 times the experiment. From the above example it is clearly observed that the four probability regions originally selected to develop the detailed probability density function are quite reasonable and are based to a number of data sources and origins, note clearly distinguished between the commercial and residential applications. A similar example for energy performance gap for a new gas boiler is given in Table 2.2.

GAS BOILER	ENERGY PERFORMANCE GAP							
	NULL		LOW		MID		HIGH	
	Impact	Prob.	Impact	Prob.	Impact	Prob.	Impact	Prob.
	€/year							
CONDENSING BOILER								
Degradation efficiency curve	0,0	60%	1400	16,0%	2800	12,0%	7000	12,0%

Table 2.2: Example distribution function for energy performance gap of Gas Boiler.

2.5 GENERAL DESCRIPTION OF EENVEST MODELS

2.5.1 Evaluation of Technical Risks.

Technical risk probability distribution functions are developed for the building elements as well as building services and RES systems in Table 2.2.

For all elements of Table 2.2, probability distributions were developed both for performance deviations from the standard performance (**energy gap**) and for additional costs due to **damage** as shown in the window example of Table 2.1.

Gap or damage analysis is generally expressed as table with Low, Medium and High Impacts and corresponding probabilities as shown in the Example table 2.3.

ENERGY PERFORMANCE GAP - DATABASE

	Low		Medium		High	
	Prob. %	Impact	Prob. %	Impact	Prob. %	Impact
Air infiltration						
Thermal bridge						
...						

Table 2.3: Example table for gap analysis probability definition

On the basis of the above example table, EEnvest has developed gap and damage probabilities for the following building envelope elements or building services or systems:

BUILDING ENVELOPE ELEMENTS	BUILDING SERVICES AND RES SYSTEMS
1. Roof	**8. Heat pump**
Flat roof	Air/air HP
Pitched roof	Air/water HP
2. Floor	Geothermal HP
Internal Insulation	**9. District Heating**
Next to air (outside)	District Heating Substation
Floor next to unheated area (es. Garage)	Customer's internal heating system
3. Walls (all typologies)	**10. Gas Boiler**
External wall:	Condensing boiler
External Cladding	**11. Biomass boilers**
Prefabricated facade	Condensing boiler
Internal Insulation	**12. Emission system**
Window facade system:	Radiant floor
Curtain wall	Radiant ceiling
Double skin	Radiators
Wall next to unheated area:	**13. Distribution system**
New insulation	**14. Cooling system**
Wall next to ground:	Chiller
New insulation	**15. Mechanical ventilation system**
4. Windows	**16. Electric system**
5. Shading system	Photovoltaic generator
6. External doors	
7. Other elements	

Table 2.4. Building and System elements with probability databases for gap and damage analysis

The above elements of Table 2.4, cover practically all possible energy saving measures that are encountered in the Residential Sector.

2.5.2 Evaluation of Financial Risks

The tool developed to implement risk evaluation and effects on budget and profitability of energy savings projects is well advanced and fully automated.

The Financial Risk evaluation includes all technical risks in terms of Performance and Damage probabilities as presented in the previous paragraph and converts them to financial risks, using the probability distributions for Gas Energy Gap, Electricity Energy Gap, and Damage as a synthesis of all probability functions of Gap and Damage analysis of all technical risks.

The above Gap and Damage probability functions are coupled together with purely Financial Risk such as:

- climate variation parameter (Heating Decree Days – HDD);
- electricity price variations;

- gas price variations.

The overall set of KPIs that the platform may generate as output are the following:

Simple payback time of the investment: Indicates how much time (years) does it take to the project to produce enough revenues to repay the initial costs of the investment.

Payback time of equity invested: Indicates how much time (years) it takes to the project to produce enough cash flows to repay the initial amount of equity invested into the project. If the investment is fully financed with equity, it equals the simple payback time indicator.

Net Present Value (NPV) of the project: It is an indicator of the economic convenience of a project. It is calculated as the sum of the present value of yearly cash flows, discounted using an appropriate discount rate. It can be applied to project cash flows (using Weighted Average Cost of Capital -WACC as discount rate) or to Free Cash Flows to Equity (using cost of capital as discount rate). NPV is a monetary value (in Euros) that indicates the amount of value created (if positive) or destroyed (if negative) by the project. Thus, if NPV is positive the investment is convenient.

Internal Rate of Return (IRR): It is one of the most widely used indicators of the profitability of a project. It is calculated as the interest rate that sets the net present value (NPV) of a series of cash flows equal to zero and it represents the rate of return of the cash invested in a project. IRR can be calculated both generically for the project, applying the formula to the overall project cash flows (regardless the financial structure of the project), or for the equity, applying the formula only to the cash flows related to equity. The IRR is important for an investor because it provides, in the form of a single number, the expected rate of return of cash invested in the project over the whole lifetime.

Debt Service Coverage Ratio (DSCR): It is an indicator widely used in the *project financing* sector to evaluate the ability of a project to repay a debt. It's calculated as the ratio between the operative cash flows generated by the project and the cash flows for debt, lease or other obligation (debt service, both for interests and principal payment) due in one year. If DSCR is over 1, the project generates enough cash to pay back the loan. Usually, banks require business plans to have a DSCR over at least 1,20 in order to ensure the bankability of the project.

Risk premium: It represents the additional return required by the investor compared the risk-free rate. As every project has its own riskiness, investors require the return to reflect the risk accordingly in order to invest in that project. Thus, the higher the risk, the higher the return expected by the investor to bear that risk. Risk premium is an important indicator to calculate the correct discount rate to be used for the calculation of the NPV of the project.

Overall simple risk indicator:

The aforementioned indicators are the KPIs provided by the platform to users. They are the results of the economic analysis of the project under uncertainty.

2.5.3 Investment evaluation and multi-benefit analysis

The multi-benefit approach follows the risk analysis and the derivation of the above KPIs of economic analysis. In addition to these KPIs, two sets of multi-benefit KPIs are estimated:

MULTI-BENEFIT PERFORMANCE for Investors

- CO2 Equivalent emission reduction
- Predicted energy savings
- Number of Jobs’ Creation

- EU Taxonomy Compliance
- Link to Sustainable Development Goals (SDGs)
- Property value increase

MULTI-BENEFIT for Project Promoters

- Thermal Comfort
- Visual Comfort
- Acoustic Comfort
- Indoor Air Quality
- Perceived physical and mental health
- Productivity

The above multi-benefit parameters are assigned economic values with weights selected by the user. Thus, the additional income generated by these parameters constitutes an additional motive for ECM (Energy Conservation Measure) implementation.

Since the multi-benefit analysis is not so input demanding and so beneficial, it is always suggested to be applied into Residential Sector projects.

2.5.4 Conclusions of replicability of EEnvest methodology in Residential Sector

2.5.4.1 The Technical Risk Replicability

On the basis of the above examination of technical and financial risk definitions, it is concluded that the databases used for the development of probability gap and damages distributions for the elements of Table 2.3, employed for the commercial sector models, does not vary fundamentally over residential sector corresponding elements of Table 2.4. This is substantiated on the basis of a detailed review of the probability definitions in the Form of Table 2.3 for all parameters referred in Table 2.4. With this review it was found, on the basis of professional Judgement, that the probability assumptions were reasonable and sufficiently low, particularly in all major impact categories.

Energy Saving Techniques and Technologies are mainly developed by the Manufacturers for the prime market of Residential buildings which constitute the vast majority (over 70%) of buildings in general and the gap and damage statistics maintained by the Manufacturers mostly are derived from Residential statistics.

Furthermore, the elements of Table 2.4 cover most building envelope interventions and system technologies that are employed in practice.

2.5.4.2 The cost-effectiveness of EEnvest replication

Consequently, the only parameter left to consider about EEnvest Replicability in the Residential Sector is the cost-effectiveness of such application which in turn is directly related with the size of the budget for ES (Energy Savings) Project in order to support the additional engineering service cost that is required to implement the EEnvest Risk Analysis. This service cost in the low budget end of investments (including 3 or 4 risk probabilities) is rather constant and includes:

1. Selecting the appropriate risks from the EEnvest platform, from a Table like Table 2.4.
2. Examine whether the selected risks are fully or partly covered by the energy simulation software that was originally used to calculated the energy parameters of the project in the first place.

– For example, if one of the risks selected is the risk of thermal bridges, check whether this parameter has been taken into account during the calculation.

- In another example, if a heat pump risk is included, check whether a degradation parameter in heat pump's performance has been included in the energy calculations or check whether the Seasonal COP included into the energy software calculations is on a high scale or it is reasonable, on the basis of published Seasonal Coefficients of performance.

3. Learn how to use and interpret EEnvest's platform for data entry and output results.
4. Test input data and outputs of EEnvest to make sure that they are free of bugs.
5. Identify risk tolerances of the Customer either by interviews or by reasonable engineering judgments for the class of the Customer.
6. Interpret the final output of EEnvest platform and make some adjustments on the basis of current social and political setup, as is the case of today's energy prices that brink down the pay back periods of the investment considerably.
7. Write an explanatory report for the customer in order to raise confidence to the project, for the contractor in order to raise his/her attention to focus on the primary areas of risk, and for the financial institutions involved, in order to explain how risks are minimized with the risk analysis just made, in order to minimize interest and insurance premiums.

The average cost of such engineering services by a senior engineer, is estimated to 3.000 to 5.000 € plus VAT. This additional cost can certainly break even if one considers the benefits expected in all partners of the project by the services outlined in items 6 and 7 in the above list.

It is now empirically estimated that the EEnvest risk analysis implementation cost should not exceed more than 10% of the total energy budget for the ES project. For example, a project with total budget of 45.000 € plus VAT, can indicatively afford a risk study of 5.000 € since this study corresponds to 10% of the total budget of the project.

On the basis of this discussion, it is estimated that an ES Project above 50.000 € should certainly benefit from the risk analysis and the multi-benefit analysis of EEnvest and all addition engineering service cost for the risk analysis will certainly pay-off in accelerating decision making and avoid costly delays in project implementation, let alone a likely minimization of interest and insurance premiums. For budgets below that, it is up to the user to decide whether such EEnvest application will become beneficial for his/her project.

2.5.4.3 Other issues of replication

It is often easy to mistake complexity in analysis with accuracy of results and to invest more in analysis refinements than justified by the benefits derived from such refinements. For instance, complicated statistical time series analysis can be applied to develop future energy price estimates. However, given the importance of expected future energy market events, such those occurring today, more appropriate values can be obtained for probability distribution of Energy princes suggested by an expert, who is often likely to provide a more accurate result than statistical techniques that cannot take into account changes in the structure of energy markets.

Once initial results are developed and evaluated, additional analysis refinements can be considered, in case that major deviations of the original impact data from current conditions. In most cases, useful refinements will require no more demanding analysis than Excel-based regression estimation or variance analysis based on historical data series of estimated impact price tags, that are directly dependent on energy prices.

3 REPLICATION POTENTIAL OF EENVEST PLATFORM IN THE RESIDENTIAL MARKET

3.1 The Agreement requirements for EEnvest Replication in the Residential sector

The Objectives of Task 6.4 and deliverable D6.3 focus on the Replication potential outside of the commercial office buildings market. This task identifies necessary requirements to replicate the EEnvest approach outside of the reference market that we are targeting during the project, to set the foreground for ease of replicability after project ends in other geographic and building use markets, with a specific focus on residential buildings.

On the basis of the analysis in paragraph 2.5.4., it was determined that the Replication potential is not a technical issue but rather a cost-effectiveness issue. As discussed in paragraph 2.5.4.2, the replication issue boils down to determining the minimum budget of a project that will benefit from a risk analysis. In paragraph 2.5.4.2 a typical budget size for a cost-effective risk analysis was estimated at 50.000 € plus VAT in order for the cost of risk analysis to break even with the benefits.

Once this target requirement is identified, the current status of EEnvest framework with respect to residential building, actions to be undertaken in the short term to eliminate shortcomings and foster extensive replicability of the approach after project end are clearly identified.

In addition, the PSAT analysis is also considered on the basis of incremental cost requirements and the effectiveness of PSAT analysis towards improvement of the business climate towards energy conservation project.

3.2 European Market Scenarios for EEvest Replication

The European Market Scenarios have been identified in paragraph 2.6 above, after extended discussions in Annex A, and in particular in paragraphs A.4 - A.5 and which are summarized in paragraphs 2.2.2 and 2.2.3.

In paragraph 2.3 the following scenarios for EEnvest Replication were identified:

3.2.1 Market 1.L: Large scale EPC upgrading applications (≥ 50.000€)

As discussed there, Market 1 is concerned with the Building EPC upgrade market, in the context of Recast EPBD generated market, at the large scale. For example, a 10-apartment building, with poorly energy performing apartments, to undergo an EPC three to four classes upgrade to class C, with an average renovation cost of 15.000 €, will have a total budget of 150.000 €. Therefore, the Residential Market is expected to offer renovation budgets in close proximity with the commercial sector buildings. Therefore, the EEnvest platform could be applied in this residential market that satisfies economies of scale at a similar fashion with the commercial one.

3.2.2 Market 1.S: Small Scale EPC upgrading applications (< 50.000€)

Market 2 segment is concerned with apartment or housing renovations at a housing level, an apartment level or group of apartments with budgets usually ranging from 10.000 to 50.000 € plus VAT tax. The Market 2 is highly likely in low rise residential buildings as well as in single houses. This market is more restricted in terms of investment on additional studies and expenses beyond the classical engineering studies for cost-optimal upgrades of EPC class.

Markets 1.L and 1.S are expected to be dominant in energy renovation investments in the Residential Buildings, due to the mandatory character of these EPC upgrades, as dictated by the Recast EPBD.

3.2.3 Market 2.L: Large scale energy saving cost-effective applications (≥ 50.000€)

This market segment is concerned with purely cost-effective energy saving applications on an apartment building which undergoes major renovations with dual objectives:

To minimize energy costs (fuel, electricity), that they have now drastically increased in whole Europe, by self financing the renovation investment, taking into account any subsidies or soft loans (low interest) available for that purpose.

To satisfy at the same time EPBD Recast requirements at least up to 2033 in the Residential sector.

Investors in this market are primarily concerned with the financial performance of the renovation project since it relies on private capital and is driven by cost-effectiveness. However, many times these investments will be coupled with EPBD Recast requirements. In any way, we consider it more appropriate to treat markets 1.L and 2.L together with the same EEnvest tools since their objectives are so intermixed.

3.2.4 Market 2.S: Small scale energy saving cost-effective applications (< 50.000€)

Exactly in the same fashion as in Market 2.L, Market 2.S hosts cost-effective, energy saving projects of the order of 10.000 up to 50.000 € value. Therefore, in this small scale, the incremental cost of additional risk analysis studies through EEnvest must be kept optional to be attractive to the owner or the developer.

3.2.5 EPC Class upgrade for investments in markets 1.L and 1.S

Different types of risks are involved in these market 1 and 2 investments. The main risk in Market 1 is the risk not to reach a prespecified EPC Class due to technological or damage risks that may occur during the construction, i.e., the risks that are exactly treated by the Technical Risk Analysis of EEnvest. Failure Risk not to reach the targeted EPC Class is smaller since not a specific target for a specific energy savings value is set, but a range of energy savings values that correspond to the targeted EPC Class.

3.3 Action Planning

3.3.1 Summary

In paragraphs 2.4 and 2.5 gap analysis performed to benchmark the current status of Eenvest framework with respect to residential buildings revealed the fact that Eenvest risk analysis models can be directly replicated in the Residential sector without loss of generality. The objective of the short-run actions to be undertaken in the short term is to eliminate shortcomings and foster extensive replicability of the approach after project end.

Short term action planning is mostly concerned on actions to encourage Eenvest promotion among Residential users without overburdening homeowners with extra financial costs for engineering studies which do not guarantee accelerated payback of engineering costs for studies or other financial returns. On the other hand, long term action planning is mostly concentrated on the improvement of the concept of “baseline” energy concept, in order to “normalize” energy savings and to minimize the uncertainty involved in climatic conditions and behavioral characteristics of a specific building.

3.3.2 General types of risks involved in Energy Saving Applications

All types of uncertainties and associated risks in energy saving projects can be classified as follows:

R1. Technical risks

R2. Technological risks involved per type of technology

R3. Baseline modeling uncertainty

R4. Measurement uncertainty/error

R5. IPMV Protocol of energy savings assessment A, B, C or D. [4]

R6. Sampling uncertainties in case of a large number of ECMs (i.e. lighting)

R7. Correlation of independent variables uncertainties

EEnvest has developed a highly pioneering approach in calculating type R1 and R2 risks on the basis of theoretical performance models with assumptions based on reasonable hypotheses, as well as relying on empirical data. For envelop ECMs, deviating scenarios are built on hard to foresee structural problems and damages due to air leakage and air-tightness, water infiltration, and thermal bridges formation. From the HVAC equipment point of view, risk curves are estimated on the basis of empirical data from manufacturers, on performance degradation with time.

However, these types of technical and technological risks are usually smaller from behavioral risks from the owners and users of the technology (risks R3, R4, R5, R6, R7).

Research with energy audits will help determine how measured energy performance deviated from the calculated through energy models. Risks R1 and R2 could be measured using A and B protocols of IPMVP. Protocols A and B of IPMVP, as presented in reference [4] can be used for measuring deviations in performance of ECMs (Energy Conservation Measures) under the EEnvest defined "risks", as long as the baseline uncertainties themselves involved are kept to a minimum, in order distinguish of EEnvest calculated technical and financial deviation versus baseline uncertainty.

3.3.3 Technical Input data complexity

The technical input data for EEnvest Technical Risk analysis was carefully reviewed. It was decided not to ask for more simplification of these input data in order to facilitate users of EEnvest platform, since the whole risk estimation methodology is based around these input data which are used for risk calculation and correspond to the monthly method of energy analysis.

This decision of ours is based on the fact that in Annex I of the new EPBD Recast is specified that the calculation of energy needs and energy use for space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems **shall be calculated using hourly or sub-hourly time intervals.**

Therefore, the level of input data complexity required in the new EPBD (Recast) for the required calculations to issue an EPC (Energy Performance Certificate) is drastically increasing over the relatively simple monthly models which are allowed today, which approximately correspond to the EEnvest input data requirements.

3.3.4 Short-term action planning

On the basis of the above remarks the following short-term actions are recommended:

- The input data for EEnvest analysis should also include the reference building energy performances for each National EPC class, as defined in Annex A and expressed in kWh/m^2, in order to check that the application of EEnvest risk models does not lead to the risk of downgrading the EPC Class of the building below the targeted EPC Class.
- The user input of annual baseline energy consumption, as defined by a single number in EEnvest, should be derived by averaging the energy consumptions of three or more consecutive years, if possible, as dictated by the Input1 datasheet of EEnvest. This way, the baseline uncertainty is minimized by avoiding entering a non representative energy consumption,

corresponding in mild weather conditions and high building vacancy rates that obscure the average energy consumption conditions.

Input data for various Elements of Table 2.4, should allow users to deselect certain interventions that:

- either they are included in the energy simulation software, used for energy calculations and therefore should be exclude from risk analysis in order not to account for theme twice (i.e. thermal bridges in envelop calculations of heat losses, air infiltration):
- or the performance is guaranteed by the supplier or contractor (i.e. Heat Pumps).

Provide a short list of all risk statistics used to develop gap and damage probability distribution summarizing the probabilities selected for each statistical levels of uncertainty for the NULL, LOW, MEDIUM and HIGH and for all elements of Table 2.3, as indicated in Tables 2.1 and 2.2. This will help EEnvest users to have a clear idea about EEnvest risk hypotheses.

3.3.5 Long -term action planning

3.3.5.1 Allow Impact level adjustments in the probability curves

Ideally, the users should be allowed to modify input data in the form of Table 2.3 to generate new or adjusted probability distributions, particularly the impact values in these probability functions, that are expected to be subjected to variations. For example, the probability curves for energy prices (gas, electricity) today have been drastically affected by present day energy crises, so that impact levels in 2.3 like input tables, to be readjusted.

Therefore, the users should be allowed to modify risk statistics used to develop gap and damage probability distribution modifying statistical of uncertainty and impact levels for the NULL, LOW, MEDIUM and HIGH regions and for all elements of Table 2.4. as indicated in Figures 2.1 and 2.2. on the basis of personal experiences or feelings about the proper of statistics. Then EEnvest Platform should automatically perform derivations of the corresponding gap and damage probability distributions to more accurately predict impacts.

3.3.5.2 EEnvest extension to estimate risk on failure to achieve targeted EPC Class

Since the EPBD induced Market 1 is expected to be a dominant one up to 2033 and even further beyond, EEnvest platform is expected to be highly desirable to the EPC upgrade market (for users in Markets 1) if the Platform estimates also the technical risk to miss targeted EPC class through the proposed project. This risk is often significant when the proposed project is only marginally achieving the desired class by comparison with the reference building performance that is entered as an input to the Platform. In these cases, the EEnvest examination of such a project may offer substantial help to avoid such unpleasant situation, i.e., to fail to reach the targeted EPC Class and suggest additional ECMs in order to comfortably achieve the desired EPC Class. In fact, such service by EEnvest Platform may help investors to include into the design only those ECMs that are needed to reach the desired EPC class without overemphasizing on ECMs, to increase the margin of safety.

3.3.5.3 Coupling EEnvest risk estimation methodology with project Baseline uncertainty

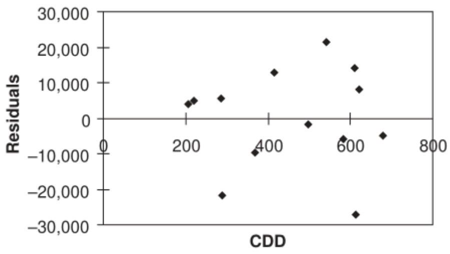
Consider Including in EEnvest methodology a monthly Baseline variable analysis of all parameters that exhibit monthly variations such as;

■ Weather variables (impacts on space heating, air conditioning, ventilation);

■ Electricity price;

■ Natural gas price.

Energy use varies from month to month because of systematic influences, such as weather, and random influences that are not clearly discernable. An example of a random influence might be variations in customer traffic in a retail environment or monthly vacation rate in the Residential Sector due to seasonal festivities. Generally, systematic influences are far greater than random influences.



Estimating Monthly Energy Use using Ordinary Least Square methods. The calculations in this section provide a basis for estimating monthly electricity and natural gas use based on heating (HDD) and cooling degree-days (CDD).

The residuals from the regression analysis indicate the non-systematic error and may be used for gap analysis in performing development of gap probability distribution. For details on how to incorporate the baseline approach into the EEnvest risk analysis methodology, see Chapter 8 of Energy Budgets at Risk (EBaR) “A Risk Management Approach to Energy Purchase and Efficiency Choices” by JERRY JACKSON [1].

Overall, by incorporating the baseline approach into EEnvest, the confidence level of the statistical analysis is drastically improved, since baseline and modelling uncertainty usually exceeds by far all other sources of uncertainty and facilitates statistics by using the non-systematic errors of residuals of the regression analysis as a sound basis to derive reliable statistics for the parameters involved.

4 REVIEW OF REPLICABILITY OF DDDQ

4.1 IDENTIFYING BARRIERS IN THE REPLICATION OF DDDQ.

4.1.1 General

The Themes 1, 2, and 3 of DDDQ (Desktop Due Diligence Questionnaire) given in paragraph 1.2.4., deals with Energy Assets and D&C (Design and Construction) techniques, whereas Themes 5 and 6 and some parts of Theme 4 deal with energy savings estimation and the M&V technique not directly dealt in EEnvest.

Due to this structure covering both D&C and M&V techniques, DDDQ tends to pose some barriers to small scale ECM investments:

B1 It is rather lengthy, most often not cost-effective to satisfy, in order to get a decent grade;

B2 The required information might be incomprehensible/difficult to obtain;

B3 Budget constrains in developing energy baselines for the residential sector;

B4 Lack of attractiveness and motivation for engagement.

4.1.2 Addressing barrier B1: downsizing the Desktop Due Diligence Questionnaire

Downsizing DDDQ may be effectively achieved by considering DDDQ as two parts: DDDQ/D&C (Design and Construction) and DDDQ/M&V (Monitoring and Verification). Both parts may have a common section referring to the quality of an Energy Audit, which is a prerequisite in both cases.

In addition to that, new versions of DDDQ-R for the Residential sector may be prepared, namely DDDQ-R/D&C and DDDQ-R/M&V, including a subset of questionnaire questions only, which are most essential to the evaluation of small-scale investments, with a modified rating system, appropriate to the subset selected.

4.1.3 Addressing barrier B2: Standardize DDDQ-R/M&V using international protocols

International Performance Monitoring and Verification (IPMVP) Protocols are widely spread and readily available in the energy audit field across Europe. Similar types of protocols are suggested by ASHRAE in Guideline 14.

IPMVP is now the most widely used and recognized M&V protocol in the world. Originally developed in the mid-1990s by the US Department of Energy, IPMVP provides a standardized, transparent approach that ensures all parties can understand the parameters to be used in evaluating the performance of an energy-saving project and hence can have confidence in the result.

The IPMVP has been translated into Bulgarian, Chinese, Czech, Japanese, Korean, Polish, Portuguese, Romanian, Russian, French, and many other languages at a national level.

Finally, to implement IPMVP there exist several freeware tools already developed on Excel or recently available online.

The Association of Energy Engineers (AEE) has trained and certified thousands of professionals across Europe on M&V protocols which are now readily available to undertake action.

In any case, a decent Energy Audit, should certainly include the specification of an appropriate energy audit protocol (A, B, C or D) should be prepared to obtain a decent grade in DDDQ.

4.1.4 Addressing barrier B3: Developing energy baselines for the Residential Sector

Although IPMNP protocols have been well established in developing energy baseline models in the Commercial Sector, for the Residential Sector such models or protocols exhibit certain peculiarities. However, such Uniform Method Projects (UMP) method for the Residential Sector have been developed as well, given in Reference [5], which includes the following protocols for the Residential Sector:

The following UMP Residential Protocol Topics are included in [5]:

1. Small commercial and residential unitary and split system HVAC heating and cooling equipment-efficiency upgrade
2. Residential furnaces and boilers
3. Residential lighting
4. Refrigerator recycling
5. Whole-building Retrofit with consumption data analysis
6. Residential behavior

Option 5 may be very effective in modeling whole-building interventions including building envelope ones. For specific technological interventions, other UMP protocols may be applied.

The M&V effort—and expenditures—should be scaled to both the program being evaluated and the accuracy necessary to inform the decision makers for whom evaluation results matter. The value of the information provided by the M&V activity is determined by the resource benefits of the program and the particular policy objectives and research questions the M&V activity aims to address.

The UMP protocols draw on best practices to recommend approaches for providing accurate and reliable estimates of energy efficiency savings, within the confines of the typical evaluation budget for that particular program. However, the UMP protocols do not offer recommendations about the levels of rigor and the specific criteria for accuracy of the savings estimates. Those issues are largely matters of policy, ease and cost of data acquisition, and availability of resources.

In any case, energy M&V protocols for the Residential Sector do require increased effort to develop and accurately tune up. Therefore, they constitute a significant barrier to the implementation to Small Scale Projects in the Residential Sector.

4.1.5 Addressing barrier B4: Make DDDQ-R/M&V readily recognized by Financial Institutions

To encourage Energy Service companies as well as private investors and building owners to accept and promote ECM measures in the Residential Sector, the DDDQ-R/M&V should be promoted to enjoy unanimous support by European Authorities and financial institutions, within the context of EED revision, to make financing for ECM projects readily available. This will constitute a critical incentive to the whole process of ECM penetration in the Residential Sector.

In parallel and to successfully promote DDDQ-R/D&C in the residential sector, new dimensions of multi-benefits for the Residential Sector should be identified and promoted, not necessarily based on speculative research of property rents versus EPC class, since most of these publications fail to recognize the strong correlation of building age with EPC class. Alternatively, the classic property appraisal techniques may be used, calculating the Net Present Value (NPV) of monthly energy monetary savings versus investment and operating costs and sharing monthly savings among owner and tenant.

4.2 THE PROPOSED STRUCTURE OF THE DDDQ-R

The DDDQ-C is structured among 6 groups (themes) of criteria with various grade scoring per group with a maximum score of 400. Starred criteria followed with a number, indicate the number of subcriteria at this criterion.

DDDQ-R/M&V will contain Themes 5 and 6 and the part of Theme 4 directly referring to monitoring the related energy consumption of monitored energy efficiency Assets. It may also contain Theme 1 questions concerning energy audits (questions1, 2, 6, and 7).

Besides, Theme 5 questions will be modified making a clear reference to Options A, B, C, and D of IPMVP and outlining statistical criteria to render baseline modeling and energy-saving targets statistically adequate.

Note that the DDDQ-C for the commercial sector is shown in Figure 4-1 together with the proposed modifications for DDDQ-R for the Residential sector, given with blue of red-letter color.

Table 4.1: DDDQ/O themes and rating criteria. With blue and red colors for the residential sector.

THEME 1: DESIGN OF ECM AND ENERGY SAVINGS CALCULATIONS	
Questions/sub questions	**Scoring**
Has an Energy Audit been carried-out to define the energy efficiency savings potential of the project?	**30**
1.a. Has the Energy Audit been carried out by an independent and certified energy auditor following required national or international standards (e.g. EN 16247-1 or ISO 50002 (Energy Audits))? SS-Residential: Audit report fully documenting ECMs based on EN 16247-2 methodologies and energy baseline uncertainties (if applicable) that are smaller than energy saving targets per ECM of for the whole building, conducted by an experienced and independent Auditor Professional	**30**
1.b. Has the Energy Audit been carried out by in-house staff or third parties having considerable expertise with Energy Efficiency projects and/or Energy Conservation Measures?	**20**
1.c. Has the Energy Audit been carried out by in-house staff with some or little Energy Efficiency expertise?	**10**
Has an Energy Consumption baseline (the reference baseline for future comparison) been calculated capturing the total energy use prior to deploying the ECM?	**25**
2.a. Did the Energy Consumption baseline calculation take into account all of the following: a.) the system boundaries (the component parts), b). the energy sources, c). a sufficiently long representative baseline period, d.) the impact of independent variables (e.g. weather, occupation, operational hours...) and e.) setting of Energy Performance Indicators SS-Residential: The energy baseline(s) developed follow IPMVP protocols B or C satisfying statistical criteria: R^2 >50%, regression parameter p-values <0,2 except one parameter with p-value<0,1	**20**
2.b. Did the Energy Consumption baseline calculation take some or not all of the requirements a.) through e.) as enumerated in the previous question? SS-Residential: IPVMP model A, or postulated energy savings or EPC estimates with conciliation factor	**8**
2.c. Has a report/document been issued showing the details of the Energy Consumption baseline calculations carried out, assumptions made and underlying data used?	**5**

Have the energy savings calculations related to the ECM been performed using a savings modeling tool officially recognised (by competent authorities) or well-reputed in the market (e.g. PHPP Passive House, BeOpt, eQuest, Openstudio/EnergyPlus, ResStock, RETScreen, HEED, etc.,…)	**10**
3.a. Has a dynamic modelling method/ tool been used? SS-Residential : DegreeDay methods for envelop interventions. Seasonal efficiencies for system equipment upgrading, monthly step calculation methods for cooling energy savings	**10**
3.b. Has a regression modelling method/tool been used?	**7**
3.c. Has a modelling method/tool been used different than dynamic modelling or regression?	**4**
Have the savings calculations been performed by experienced modellers, preferably with required qualifications and/or certifications?	**5**
Has a report been issued showing the ECM/savings modeling process including all modeling assumptions, modeling inputs and outputs and possible modeling errors and limitations?	**5**
Has a report been issued listing all the ECM in detail (existing conditions, proposed renovation,…) preferably ranked based on their energy savings potential with their associated implementation cost (investment cost)?	**5**
Does the project envisage only one ECM (e.g. HVAC retrofit) or does the project envisage multiple ECM (e.g. HVAC retrofit and relighting and/or other ECM).	
7.a. If multiple ECM have been envisaged is there clear evidence that calculations have taken into account interactions (interdependencies) between measures and their impact on heating and cooling loads (demand), e.g. efficient relighting renovation might increase heat demand.	-10
TOTAL	80

THEME 2: IMPLEMENTATION OF ECM (=ENERGY CONSERVATION MEASURES)	
Questions/sub questions	**Scoring**
Is there an overall 3rd party (Facilitator, independent engineer, architect,…) responsible for the co-ordination and the implementation of the Energy Conservation Measures?	**30**
8.a. If not, has as an in-house co-ordinator with proven experience in Energy Efficiency projects been appointed to co-ordinate and oversee the implementation of the ECM?	**25**
Have the installers (contractors) of the ECMs been assigned based on a bid process that is also taking into consideration quality criteria (proven expertise, past projects, certifications,…)? SS-Residential: N/A	**5**
Has the appointment of the installers been influenced by other elements than quality and price (e.g. personal relationship, family, by reference,…)? SS-Residential : N/A	**-5**
Is there a well-defined installation plan of the ECM with implementation deadlines agreed with the contractor(s)? SS-Residential : Is there a well-defined installation plan of the ECM	**10**
Has a process been put in place for the possible adjustment of the initially committed implementation deadlines?	**3**

SS-Residential : N/A	
Does the contract with the installers (contractors) provide for penalties applicable in order to incentivize the installers not to exceed the installation deadlines?	**3**
Does the contract with the installers (contractors) request compliance with technical standards relevant to the implementation of the ECM?	**5**
Does the contract with the installers (contractors) provide for compliance with official permits relevant to the implementation of the ECM?	**5**
Has an agreed process been defined on how the operational performance (also called commissioning) of the ECM are going to be verified?	**3**
Is the verification methodology (visual inspection, sample spot measures, functional testing, performance testing,..) per ECM/group of ECMs been defined and agreed upon?	**3**
Does the operational performance verification include verification of the necessary tools (e.g. meters, energy monitoring system) allowing collection and analysis of the performance of the Energy Efficiency Assets after installation?	**3**
Is the operational performance verification being done or supervised by a qualified or experienced energy efficiency expert?	**2**
Are there or will there be acceptance records evidencing formal acceptance by the client of the ECM implemented?	**2**
Does the acceptance process include documentation of technical instructions and/or operational information (System or Operator's guide) related to the Energy Efficiency Assets in order to ensure their optimal functioning and performance during the operational phase?	**3**
Does the acceptance process include training of users or operating staff on the impact of the EEA, their correct operation , detection of issues and possible remediation?	**3**
TOTAL	80

THEME 3: MAINTENANCE AND OPERATION OF THE ENERGY EFFICIENCY ASSETS	
Questions/sub questions	**Scoring**
Does the project foresee a Maintenance services contract with a specialized 3rd party for those ECM that need maintenance in order to function optimally?	**80**
23.a. Has the Maintenance contractor been procured based on a bid process that is also taking into consideration quality criteria (proven expertise, past project, certifications SS-Residential: Has a bid process also taking into consideration quality criteria is prepared	**15**
23.b. Is there or will there be an agreed Maintenance Plan with the contracted party clarifying the role and responsibilities of the parties including maintenance schedules	**5**
23.c. Does the Maintenance agreement clarify the communication between the parties including the issues logging procedure and the escalation process?	**5**
23.d. Does the contract with the Maintenance Party deal with different types of malfunction (e.g. normal, urgent, critical) and their required repair times in order to safeguard optimal functioning of the Energy Efficiency Assets	**10**
23.e. Does the contract with the Maintenance Party provide for penalties for non-compliance with repair times and/or plans?	**25**

23.f. Does the contract with the Maintenance Party provide for a system of penalties for repetitive or multiple malfunctions?	**15**
23.g. Does the contract with the Maintenance Party provide for a system of recording malfunctions and repair lead times for future reconciliation and proof?	**5**
If no maintenance services contract has been foreseen, is there a formal internal maintenance plan based on the technical instructions and predictive maintenance requirements from the System or Operator's Guide ?	**20**
If no maintenance services contract has been foreseen, is the maintenance plan executed by in-house expert technical staff with energy efficiency expertise or based on relevant qualifications or certifications?	**35**
TOTAL	80

THEME 4: MONITORING OF THE ENERGY EFFICIENCY ASSETS AND THEIR ENERGY CONSUMPTION	
Questions/sub questions	**Scoring**
Does the project foresee monitoring of the Energy Efficiency Assets and the related energy consumption?	60
26.a. Have key performance indicators (e.g. heating degree days, kWh consumed per building, kWh consumed per user, guaranteed energy savings,,…) been selected and are these representative of the system operation and energy performance?	**10**
26.b. Is there a well-defined methodology for tracking, analyzing and assessing the performance of the Energy Efficiency Assets against expected savings and selected performance indicators?	**10**
26.c. Does the performance monitoring include a data collection system for energy data collection (meters, submeters, gateway,…)?	**10**
26.d. Does the performance monitoring include an Energy Management System allowing for the analysis and performance of the collected energy data?	**10**
26.e. Does the performance monitoring include a Building Management System?	**5**
26.f. Does the performance monitoring include automated fault detection and diagnostic tools?	**5**
26.g. Does the training of operating staff responsible for the optimal operation of the Energy Efficiency Assets include specific training on the adequate use of the monitoring systems?	**10**
TOTAL	60

THEME 5: MEASUREMENT AND VERIFICATION OF THE ENERGY SAVINGS	
Questions/sub questions	**Scoring**
Has a comprehensive Measurement & Verification approach been defined typically including the following core steps: 1. Documentation of the baseline energy consumption, 2. Establishment of the M&V plan, 3. Operational performance verification, 4. Energy data collection and 5. Savings verification and reporting?	**40**
Has a simplified Measurement & Verification approach been chosen, e.g. focus on individual measures complemented by e.g additional controls or testing?	**30**
Has the Measurement & Verification approach been defined following any certified M&V protocol such as IPMVP or ISO50015?	**10**
Is the Measurement & Verification being serviced or supervised by a M&V certified expert?	10
30.a. Is the M&V being serviced by an independent M&V certified expert?	**10**

30.b. Is the M&V being serviced by an in-house or by the installer/contractor M&V certified expert?	**5**
TOTAL	60

THEME 6: COMMUNICATION WITH AND TRAINING (AWARENESS) OF USERS AND/OR OCCUPANTS	
Questions/sub questions	**Scoring**
Does the project include a defined approach for collection, verification and implementation of users' requirements (e.g. comfort parameters, indoor air quality, illumination levels, operating hours,…)?	20
31.a. Does the users' requirements approach take into account legal compliance, existing standards and good practices?	**5**
31.b. Does the user's requirements approach include periodic reviews for compliance with the users' requirements?	**5**
31.c. Does the users' requirements approach foresee corrective actions in case of deficient compliance?	**5**
31.d. Does the users' requirements approach include users satisfaction surveys to test compliance with users' requests?	**5**
Is there a user information process dealing with the communication of the implemented energy efficiency improvements?	**6**
Is there an energy awareness program (campaign) defined to optimize user and occupants' energy awareness and behavior (e.g. training sessions, poster campaigns, brochures,…)?	**14**
TOTAL	60

5 REPLICATION POTENTIAL OF DDDQ IN THE RESIDENTIAL MARKET

5.1 EUROPEAN MARKETS FOR EENVEST METHODOLOGY PLATFORM

On the basis of the cost effectiveness concept, the feasibility of DDDQ-R depends directly on the size (budget) of a proposed energy savings project, in order to render the additional development cost as cost-effective.

5.1.1 Market 3.L: Large scale EPC upgrading applications (≥100.000€)

Market 3.L is concerned with the Building EPC upgrade market, in the context of Recast EPBD induced market, at the large scale. For example, a 10-apartment building, with poorly energy performing apartments, to undergo a three to four EPC classes upgrade to class C, with an average renovation cost of 15.000 €, it will have a total budget of 150.000 €. Therefore, the Residential Market is expected to offer renovation budgets in close proximity with the commercial sector buildings. Therefore, the EEnvest tool could be applied in this residential market that satisfies economies of scale at a similar level with the commercial level.

5.1.2 Market 3.S: Small Scale EPC upgrading applications (<100.000€)

Market 3.S segment, is concerned with apartment or housing renovations at a housing level, an apartment level or group of apartments with budgets usually ranging from 15.000 to 100.000 € plus VAT tax. The Market 3.S is expected to be created in low rise and high-rise residential buildings. This market is more restricted in terms of investment on additional studies and expenses beyond the classical engineering studies for cost-optimal upgrades of EPC class.

Markets 3.L and 3.S are expected to be dominant in the Residential Buildings energy renovation investments, due to the mandatory of these EPC upgrades, as dictated by the Recast EPBD.

5.1.3 Market 4.L: Large scale energy saving cost-effective applications (≥ 100.000€)

This market segment is concerned with purely cost-effective energy saving applications on an apartment building which undergoes major renovations with dual objectives:

To minimize energy costs (fuel, electricity) that they have now drastically increased in whole Europe, by self financing the renovation investment, taking into account any subsidies or soft loans (low interest) available for that purpose.

To satisfy at the same time EPBD Recast requirements at least up to 2033 in the Residential sector.

Primarily investors in this market are mostly concerned with the financial performance of the renovation project since it mostly relies in private capital. However, many times these investments will be coupled with EPBD Recast requirements. In any way, we consider it more appropriate to treat markets 3.L and 4.L together with the same EEnvest tools since their objectives are so intermixed.

5.1.4 Market 4.S.: Small scale energy saving cost-effective applications (≤ 100.000€)

Exactly in the same fashion as in Market 3.L, Market 3.S hosts cost-effective, energy saving projects of the order of 15.000 to 100.000 € value. Therefore, in this small scale, the investment cost of additional studies through EEnvest must be kept to a minimum in order to be attractive to the owner or the developer.

5.2 RISK ASSESSMENT FOR EACH MARKET SEGMENT.

5.2.1 Energy savings in market segments 4.L and 4.S

Applications in Market segments 4.L and 4.S required estimation of energy savings with the proposed interventions. Again, energy savings should be calculated on the basis of the corresponding definition of EED in Article 2:

Article 2 - Definition (7): ‘energy savings’ means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalization for external conditions that affect energy consumption.

Normalizations is most often realized by the concept of energy consumption baseline, as developed in ISO EN 50001. Since EEnvest risk analysis does not deal directly with the normalization and this estimation involves significant risks, this concept is introduced in the process of Desktop-Due-Diligence Questionnaire (DDDQ). Therefore, since the normalization process is considered so important by the EED, the DDDQ cannot be considered as marginal to the whole EEnvest methodology, but constitutes an integral part of it. As discussed in paragraph 2.2.4, there are six themes in the DDDQ:

THEME 1: Design of an ESM and energy saving calculations (16 questions)

THEME 2: Implementation of an ESM (= Energy Efficiency Assets) (16 questions)

THEME 3: Maintenance and Operation of the energy efficiency Assets (9 questions)

THEME 4: Monitoring of the energy efficiency assets and their energy consumption (7 questions)

THEME 5. Measurement and Verification of the energy savings (6 questions)

THEME 6. Communication with awareness and training of users and/or occupants (7 questions)

Themes 4, 5 and 6 are essential in the normalization process, usually mentioned as Monitoring &Verification., exactly as described in Theme 5.

Therefore, all six themes are necessary to evaluate market 4.L and 4.S type investments. However, for type 4.S small scale investments, there is a need to downsize and simplify the work required to fill the DDDQ. This issue is discussed in paragraph 5.1.2.

5.2.2 EPC Class upgrade for investments in markets 3.L and 3.S.

Different type of risks is involved in these markets 3.L and 3.S investments, in a similar fashion as in markets 1.L and 1. S. The main risk here is the risk not to reach a prespecified EPC Class due to performance gaps or damage risks that may occur during the purely technical risks. The issue of normalized energy savings is not evaluated here. What is really important here is to evaluate individually the energy performance of each energy efficiency intervention to verify that all major technical assumptions are fulfilled so that theoretical energy savings assumptions are satisfied and the targeted EPC Class is reached. The failure risk of reaching the targeted EPC Class is here much smaller than in the case of normalized energy savings estimation since here we don’t target a specific energy savings value but a range of energy savings values that correspond to the targeted EPC Class.

In these cases, Themes 4, 5 and 6 in the DDDQ process need not to be considered since normalized energy savings are not calculated.

5.3 ACTION PLANNING

5.3.1 General

Short term action planning is mostly concerned with downgrading the requirements for DDDQ in order to encourage EEnvest promotion among Residential users without overburdening home owners with extra financial costs for engineering studies which do not guarantee additional payback and other financial returns. On the other hand, long term action planning is mostly concentrated on the nature of risk and damage curves and the corresponding data bases out of which the risk curves were developed.

5.3.2 Short-term action planning

In Chapter 6, a modified Residential version of DDDQ/R is presented with some simplifications, marked as "SS-Residential". In questions marked as such, the user may ignore the original question and answer only those questions. The questions marked as SS-Residential: N/A (Not Applicable), need not to be answered for residential investments.

On the basis of this version the following recommendations for the use of DDDQ are made:

Market 3.L: Large scale EPC upgrading applications (≥100.000€): Full Use of DDDQ/R

Market 3.S: Small Scale EPC upgrading applications (<100.000€):

Only Themes 1, 2, 3 and 6 of DDDQ/R

Market 4.L: Large scale energy saving cost-effective applications (≥ 100.000€) Full Use of DDDQ/R

Market 4.S: Small scale energy saving cost-effective applications (≤ 100.000€)

Only Themes 1, 2, 5 and 6 of DDDQ/R

Finally for ES projects below 50.000 €, it is estimated that no DDDQ/R may easily become cost-effective.

5.3.3 Long-term action planning

DDDQ-R structure and criteria in paragraph 4.2 closely follows DDDQ-C criteria after some relaxation of requirements on processes of auditor certification that my create bottlenecks in ECM application due to lack of great numbers of certified systems or auditors across European ECM market.

This relaxation will be considered at the long run and after the completion of EEnvest project. The same is true for the requirement to satisfy statistical criteria in the energy audits conducted in order to develop the corresponding energy baselines.

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ANNEX A: THE EMERGING EPBD DRIVEN MARKET IN THE BUILDING SECTOR

A.1 OBJECTIVES AND REQUIREMENTS OF EPBD RECAST

A.1.1. General

Over the last 10 years, the Energy Performance Certificates have been established themselves in the building and Housing sectors of all member states after the EPBD (Energy Performance of Buildings Directive), fist emerged as EPBD/2002/91/EU. It is now recognized that this directive as well as the new version of it emerged as EPBD/2010/31, did not affect much the real estate renovation market and therefore EPCs (Energy Performance Certificates) have had a minor influence in this market.

The Residential sector includes the vast majority of all buildings in the Building Sector and therefore the replication potential of EEnvest platform in this sector is of paramount importance to achieve significant penetration of this platform to the Building Sector.

This is now recognized by the Commission that has decided to issue in a new draft of recast EPBD, which now will include Mandatory Energy Performance Standards (MEPS) summarized schematically as follows:

55% cut of CO2 emissions from the Building Sector in Europe by 2030

Eliminate completely CO2 emissions from the Building Sector by 2050

Promote Near Zero Energy Buildings (nZEB) by 2030 (~ A EPC class)

Zero Energy Buildings (ZEB) by 2050

A.1.2 The Recast EPBD requirements

Most of the European buildings belong in classes D, E, F and G. i.e., the worst energy classes. according to the recast EPBD.

Article 8 – 10 of the Commission’s draft of Recast EPBD require Member States to ensure that all existing buildings, owned by public bodies or non-residential buildings, shall satisfy the **Minimum energy performance standards (MEPS)** as follows: F as a minimum EPC Class by 2027 and E as a minimum EPC Class by 2030. These deadlines are extended to 2030 and 2033 respectively for the Residential buildings.

Furthermore, member states are asked to establish specific timelines for the above buildings to achieve higher energy performance classes by 2030, 2040 and 2050, in line with the pathway for transforming the national building stock into zero-emission buildings. Consequently, it is expected that most member states will require buildings to reach higher EPC classes than the corresponding classes E and F of all buildings by 2030 and 2033, most likely EPC class D or even C.

The focus on the very lowest performing classes of the building stock ensures that efforts focus on buildings with the highest potential for decarbonization, energy poverty alleviation and extended social and economic benefits.

Member States are asked to support compliance with minimum energy performance standards with an enabling framework including financing support, in particular targeting vulnerable households and people affected by energy poverty or living in social housing, technical assistance, and monitoring mechanisms. The proposed provisions allow Member States to exclude several categories of buildings from the obligation to comply with minimum energy performance standards.

A.2. THE OBJECTIVES OF NEW DRAFT OF RECAST EPBD

By December 15, 2021, the Commission published a new version of buildings directive, entitled as a proposal for recast EPBD.

The main objectives of this revision are reducing buildings' greenhouse gas (GHG) emissions and final energy consumption by 2030 and setting a long-term vision for buildings towards EU-wide climate neutrality in 2050. In order to meet them, the initiative is grounded in several specific objectives: to increase the rate and depth of buildings renovations, to improve information on energy performance and sustainability of buildings, and to ensure that all buildings will be in line with the 2050 climate neutrality requirements. Strengthened financial support and modernization and system integration are levers to deliver on these objectives.

The recast EPBD is scheduled to set the overall vision for new and existing buildings that applies across building-related provisions of the other "Fit for 55" initiatives[1]. By upscaling actions to reduce energy consumption in the building sector, the EPBD will also contribute to the delivery of the overall energy efficiency targets set in the Energy Efficiency Directive (EED). The higher number of renovations triggered by the EPBD proposal and by the requirement for new buildings to install heating systems with zero direct greenhouse gas emissions and to integrate renewable energies to become zero-emission buildings will enable the indicative 2030 target for the share of renewables in buildings' final energy consumption in line with the Renewable Energy Directive (RED). The proposal will support the replacement of inefficient fossil-fuel boilers by systems with no direct GHG emissions, such as heat pumps and other renewable based technologies

The proposal similarly complements products legislation, e.g., the Energy Labelling Regulation (ELR), which incentivizes consumers to purchase best-in-class energy-related products and appliances placed in buildings. The EPBD works in tandem with the Eco-design

Directive (ED), which sets energy performance and other environmental performance requirements on energy-related products, in particular for technical building systems (e.g., boilers, heat pumps or light sources) and equipment used in buildings (e.g., household appliances). The performance of construction products is addressed in the Construction Products Regulation (CPR) and the proposal also contributes to continuous progress towards climate adaptation, through the provisions related to strengthening of the climate resilience of buildings.

In parallel, the strengthened information tools of the EPBD, which will include also a carbon metric, will help financial investors monetize the benefits of buildings decarbonization and household or commercial actors to better factor in the economic benefits of building renovations and their repayment plans. These aspects are also aligned with the building-related elements of the EU taxonomy for sustainable activities[2].

[1] List of proposals: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en#renovating-buildings-for-greener-lifestyles.

[2] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en.

A.3 THE CURRENT STRUCTURE OF EPCS IN THE RESIDENTIAL SECTOR

A.3.1. The European Standard EN 15217:2007 for rating Energy Performance Certificates (EPCs)

In 2007, was published the Standard EN 15217:2007 entitled “Energy performance of buildings — Methods for expressing energy performance and for energy certification of buildings”.

In this standard, the rating system of buildings in Classes A, B, C, D, E, F, G was determined with the following rules concerning the Energy Performance Certificates (EPC):

1) Class A if EP < 0,5 Rr
2) Class B if 0,5 Rr ≤ EP < Rr
3) Class C if Rr ≤ EP < 0,5(Rr + Rs)
4) Class D if 0,5 (Rr + Rs) ≤ EP < Rs
5) Class E if Rs ≤ EP < 1,25 Rs
6) Class F if 1,25 Rs ≤ EP < 1,5 Rs
7) Class G if 1,5 Rs ≤ EP

were
EP: is the energy performance of rated building

Rr: representing the requirements for new or modernized buildings. It is the main benchmark used to evaluate of a building;

Rs: representing the average state of the building stock as a benchmark. It corresponds to an average energy efficiency of around 50% of the national or regional building stock (the median value).

As a rule of thumb Rs ~ 2 Rr. Around the above rating classes of EPCs, most member states have based their own EPC systems. However, some countries have introduced additional Classes, particularly by subdividing classes, in order to achieve better resolution in the high energy efficiency classes.

Table A.1: Range of EPC Classes according to EN 15.217:2007 with Rs=2.Rf

EPC Limits	Lower	Upper	Average	Savings to Jump to A Class	Savings to Jump from G Class
A	0	0,5	0,25	-	92,9%
B	0,5	1	0,75	66,7%	78,6%
C	1	1,50	1,25	80,0%	64,3%
D	1,50	2	1,75	85,7%	50,0%
E	2	2,5	2,25	88,9%	35,7%
F	2,5	3	2,75	90,9%	21,4%
G	3	-	~3,5	92,9%	-

In the column “Average”, the mean value of upper and lower limit is calculated. In the next column, Energy Savings requirements are calculated with the formula:

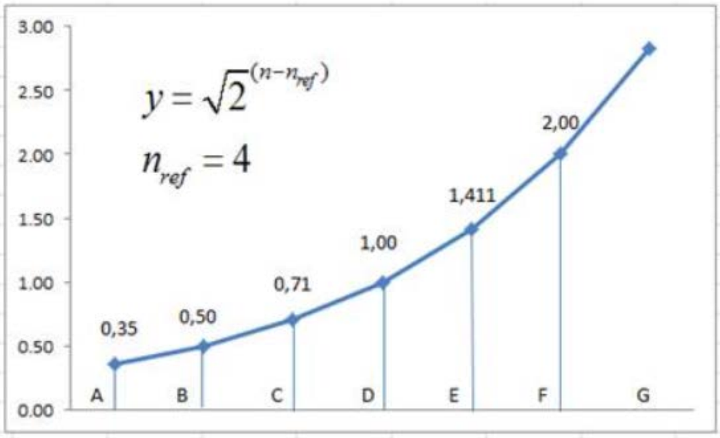
(Energy Savings required to jump) = 1 – (A average class value)/(Other average class value)

Finally in the last column, the calculation formula becomes:

(Energy Savings required to jump) = 1 – (Other average class value)/(G average class value)

A.3.2 The new standard ISO 52003/2017 for EPC classes rating in EPBD Recast

In annex I of the new EPBD Recast Directive, member States are asked to describe their national calculation methodology based on Annex A where the rating classes have as follows:



were n is the number of each class (Class A has n =1) and $n_{ref} = 4$ and the numbers given correspond to lower limit of each class.

Table A.2: Average values of EPC Classes and energy savings required to jump to other classes.

EPC Class lower limit		Average	Savings to Jump to A Class	Savings to Jump from G Class
A	0,35	0,43		85,8%
B	0,50	0,60	29,3%	79,9%
C	0,71	0,85	50,0%	71,5%
D	1,00	1,21	64,6%	59,8%
E	1,41	1,71	75,0%	43,1%
F	2,00	2,25	81,0%	25,0%
G	2,5	3	85,8%	

By comparing Table A.2 with Table A.1 it is observed that are relatively similar although the new EPBD recast method is a little more conservative. The Table A.2 rating will be the dominant on the member states in the next coming years.

A.3.3. German and French EPC Classes

At next in Table A.3 we briefly present the German and in Table A.4 the French EPC Classes which closely resemble those of the above Figure.

Table A.3 " German EPC Classes for primary energy

GERMANY EPC CLASSES	kWh/m2 average per annum	ES for Jump to Class A+
A+	12,5	-
A	37,5	66,7%
B	62,5	80,0%
C	87,5	85,7%
D	112,5	88,9%
E	150	91,7%
F	175	92,9%
G	225	94,4%
H	>250	96,4%

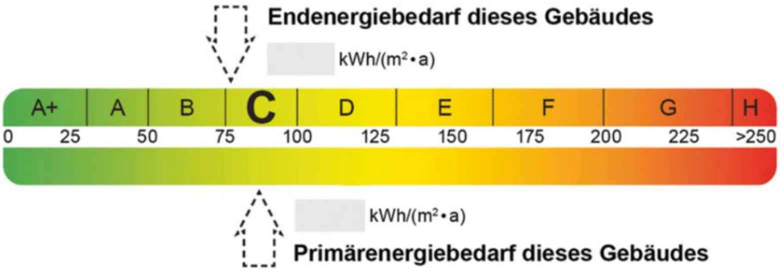


Table A.4 French EPC Classes for primary energy

FRANCE EPC CLASSES	kWh/m2 per annum	ES for Jump to Class A
A	25	
B	70	64,3%
C	121	79,3%
D	197	87,3%
E	281	91,1%
F	391	93,6%
G	>450	95%

A.3.4 The math of EPC Classes following the Hellenic EPC System

In the following tables, it is assessed the energy efficiency potential, created by the new Draft EPBD Recast for energy efficiency projects in the Residential Sector, based on the Hellenic EPC Classes which closely follow those of *to* EN 15.217:2007.

In Table A.5 typical average primary energy consumption is given per EPC Class.

Table A.5: Typical average Primary Energy (PE)consumption in kWh/m2 per EPC Class

PE kWh/m2	**Climatic Zones [DegreeDays (°)]**				
EPC	**A (702)**	**B (947)**	**C (1687)**	**D (2537)**	**E (3085)**
A+	20,5	21,5	30,5	31,5	32,0
A	32,5	36,5	48,0	54,0	55,0
B+	52,5	61,5	82,5	89,0	90,0
B	76,0	89,5	117,0	130,0	133,0
C	104,7	123,3	161,1	179,0	185,0
D	140,3	165,2	215,9	239,9	245,0
E	188,0	221,4	289,4	321,6	340,0
F	252,0	296,7	387,9	431,0	440,0
G	337,7	397,7	519,9	577,6	590,0

This Table was derived on the basis of the following hypothesis for the EPC Classes subdivision given in Table A.6:

Table A.6.: Subdivision of EPC Classes in comparison of Energy Performance (EP) of the Reference Building (Rb)

EPC Class	**Ratio by Ref. Building**
A+	EP ≤ 0,33 Rb
A	0,33 Rb < EP ≤ 0,50 Rb
B+	0,50 Rb < EP ≤ 0,75 Rb
B	0,75 Rb < EP ≤ 1,00 Rb
C	1,00 Rb < EP ≤ 1,41 Rb
D	1,41 Rb < EP ≤ 1,82 Rb
E	1,82 Rb < EP ≤ 2,27 Rb
F	2,27 Rb < EP ≤ 2,73 Rb
G	2,72 Rb < EP

NOTE in Table A.6
EPC: Energy Performance Certificate
EP : Energy Performance
Rb: Reference Building

Finally in Table A.7 the energy savings required to jump from G all other EPC Classes are given, calculated as follows: Energy Savings (from G to X class) = 1- X/G

Table A.7: Energy Savings (ES) required to jump from Class G to the final EPC Class.

ES from G	**Climatic Zones [DegreeDays (°)]**					**Average Energy Savings**
EPC class Jump	**A (702)**	**B (947)**	**C (1687)**	**D (2537)**	**E (3085)**	
G → A+	93,9%	94,6%	94,1%	94,5%	94,6%	94,4%

G → A	90,4%	90,8%	90,8%	90,7%	90,7%	90,7%
G → B+	84,5%	84,5%	84,1%	84,6%	84,7%	84,5%
G → B	77,5%	77,5%	77,5%	77,5%	77,5%	77,5%
G → C	69,0%	69,0%	69,0%	69,0%	68,6%	68,9%
G → D	58,5%	58,5%	58,5%	58,5%	58,5%	58,5%
G → E	44,3%	44,3%	44,3%	44,3%	42,4%	43,9%
G → F	25,4%	25,4%	25,4%	25,4%	25,4%	25,4%
G → G	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

Table A.8: Energy savings required for one Class jump to the above Class.

ES-1 Class	**Climatic Zones [DegreeDays (°)]**					**Average Energy. Saving**
EPC Jump	**A (702)**	**B (947)**	**C (1687)**	**D (2537)**	**E (3085)**	
A+						
A	36,9%	41,1%	36,5%	41,7%	41,8%	39,6%
B+	38,1%	40,7%	41,8%	39,3%	38,9%	39,8%
B	30,9%	31,3%	29,5%	31,5%	32,3%	31,1%
C	27,4%	27,4%	27,4%	27,4%	28,1%	27,5%
D	25,4%	25,4%	25,4%	25,4%	24,5%	25,2%
E	25,4%	25,4%	25,4%	25,4%	27,9%	25,9%
F	25,4%	25,4%	25,4%	25,4%	22,7%	24,9%
G	25,4%	25,4%	25,4%	25,4%	25,4%	25,4%

It is observed from Tables 2.7 and 2.8, that the ES requirements from any Class to another Class is practically independent from the Climatic Zone and therefore average Energy Savings are given in last columns of these Tables. This is reasonable since all EPC Class subdivisions are governed by Table A.2. and therefore, their proportionality is independent from Climatic Zones.

A.3.5. Forecasting of EPC requirements up to 2033

All interventions to G Class buildings will be performed in one step (E Class up to 2033) since is not reasonable to mobilize in two steps (F Class in 2030 and E Class in 2033) achieving the above targets.

It is observed that the two classes jump, from G to E, requires energy savings of 44% (Table A.3) and from F to E savings of 24,9% (Table A.4). Assuming in one member state the G Class residential buildings correspond to 30% of total and the F Class buildings of 20%, then the total energy savings and emission reductions are estimated equal:

44% (30%) + 24,9% (20%) = 18,2%

This figure lags significantly behind the 55% reduction target defined into the “Fit for 55” package, i.e. 55% reduction target that is officially adopted by the Commission.

Consequently, higher building Classes are expected to be adopted by member states in order to reach this 55% target. In the following Table A.9, it is assumed that member states impose in all old buildings to reach Class C by 2033. In this table the required savings are calculated as before from Table A.7 and given in Table A.10. The percentage of buildings in each Class is taken by assumption.

Table A.9: Estimated Residential renovation market up to 2033.

Class Jump	Required Savings	Percentage of buildings	Product
D → C	25,2%	10%	3,8%
E → C	44,6%	10%	6,7%
F → C	58,4%	20%	11,7%
G → C	68,9%	30%	20,7%
SUM			**42,8%**

Then the total energy/emission reductions are calculated by 42,8%.

Therefore, it is forecasted that the Residential Sector will have to drastically renovate, particularly for buildings from D to G.

Table A.10: Energy Savings required to Jump to C Class

ES to C	**Climatic Zones [DegreeDays (°)]**					**Average Energy Savings**
EPC Jump	**A (702)**	**B (947)**	**C (1687)**	**D (2537)**	**E (3085)**	
D → C	25,4%	25,4%	25,4%	25,4%	24,5%	25,2%
E → C	44,3%	44,3%	44,3%	44,3%	45,6%	44,6%
F → C	58,5%	58,5%	58,5%	58,5%	58,0%	58,4%
G → C	69,0%	69,0%	69,0%	69,0%	68,6%	68,9%

A.4 THE RECAST EPBD INDUCED EUROPEAN MARKET POTENTIAL

On the basis of the above findings, we attempt here to provide a rough estimate of the total market potential of the First Stage of EPBD up to 2033 to reach C Class all over Europe.

As stated in Recital (21) of Recast EPBD proposal, "The necessary decarbonisation of the Union building stock requires energy renovation at a large scale: almost 75% of that building stock is inefficient according to current building standards, and 85-95% of the buildings that exist today will still be standing in 2050"

A similar statement is made in in Recital (4) of the new Recast EED (Energy Efficiency Directive): "75% of the Union´s building stock has a poor energy performance".

In Greece there is approximately 2 million residential houses in D class of lower. Assuming an average renovation cost of 15.000 per house, then the total renovation budget up to 2033 is approximated as 30 billion euros and on an annual basis 2,7 billion Euros.

Based on the above recitals and stretching the above figure on a European Basis, on the basis of population figures (447 million for EU and 10,4 million for Greece), then the total budget up to 2033 is 1,3 trillion euros and 118 billion euros annually.

A.5. Cost-effective and Multi-benefit European market potential

A.5.1 General

Despite the Recast EPBD driven market Potential, a relatively smaller market potential is expected to be created due to pure market driven economics such as:

- Cost -effectiveness of energy efficiency investments
- Multiple Multi-benefit drives including:
- Real Estate property value upgrade (both for sale and for rent)
- Healthy and ventilated internal environment of buildings, minimizing suspended dust and VOCs (Volatile Organic Carbon), by introducing heat recovery ventilation
- Highly comfortable temperature and moisture during heating and cooling period, by upgrading HVAC systems (Heating, Ventilation and Air Conditioning) and automation controls
- Minimizing internally external noise and comfort conditions near the windows by installing super insulated windows

This market is expected to be developed for EPC classes of buildings because energy saving cost-effective applications there exist in all building classes. Therefore, and as the recast EPBD is promoting building renovation, the Cost-effective/Multi-benefit driven market potential is expected to grow in parallel.

Up to 2033, this energy efficiency market is not expected to generate significant business in the Residential sector since all partners in energy efficiency Services will face limitations in staff development. Training and organization, due to the expected explosion of the EPBD driven market which is expected for a country like Greece states to reach a figure of 30 billion euros or more up to 2033 in the next eleven years.

However, at the opposite side, the Recast Energy Efficiency Directive (EED) is expected to generate certain market for Cost-Effective energy savings applications in the Residential sector as explained in the next paragraph.

Anyhow and beyond 2033, the energy efficiency services are expected to be ready to offer these more advanced services for Cost-effective/Multi-benefit market which is expected to cover the more sophisticated EPBD driven demand for these services.

Consequently, these two markets, driven by the EPBD and the Economic/Multi-benefit/EED are expected to grow in parallel up to 2033, with the EPBD market being the dominant one.

A.5.2 The Recast EED induced market potential

In 14.7.2021, the proposal for a Directive on Energy Efficiency (recast) was issued by COM(2021) 558 final 2021/0203 (COD). In December 2018, a new 2030 Union headline energy efficiency target of at least 32,5% (compared to projected energy use in .2030) was included in Recital (6) of this Recast Directive.

The main concept of this Recast Directive revolves around the concept of Cost-Effective Energy Savings which are defined in Article 2 as follows:

Article 2 - Definitions (7): 'energy savings' means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption

This definition is kept the same from the previous edition of EED 2012/27/EC and revolves around the concept of "normalization" which is usually performed through the concept of the so-called energy baseline, as defined and explained in ISO EN Standard 50001.

Companies in the energy sector (gas and electricity generation, transmission and distribution) will probably be obliged to develop energy saving programs for their customers, promoting annual savings in their energy consumption by 1,5% up to 2031. Obviously, this obligation includes also the Residential Sector but is not expected to generate much income for energy service companies there, due to the fact that energy sector companies are expected to fulfill this obligation by promoting typical energy efficiency applications in the Residential sector such as lighting, and equipment replacement and maintenance.

Article 11 imposes obligations about energy audits and energy management systems for all companies that consume more than 10 TJ and 100 TJ of energy respectively.

The threshold of 100TJ corresponds to 27,8 million kWh. With a load factor 50%, the general installed energy capacity for facilities exceeding this level of energy use for all forms of energy is estimated as follows:

27.800.000 kWh/ (8760 hours/year * 50%) = 6350 kW

Therefore, the 100TJ correspond to 6350 kW installed capacity and the 10 TJ to 635 kW capacity.

Consequently, in both cases, due to the high installed energy capacity criteria, Residential sector buildings do not match these requirements.

A.6 CONCLUSIONS

From the above on the effects of EED induced energy efficiency market potential, it is concluded that this EED induced potential is rather narrow in comparison of the EPBD Recast market potential which amounts up to 2 to 3 trillion euros up to 2033 in Europe, as discussed in paragraph 2.T4. The basic market potential for cost-effective energy saving applications does exist for the buildings in the Tertiary sector

However, some cost-effective market potential still remains in the Residential sector, purely based on economic grounds, not requiring for government subsidies and state grants.

Therefore, the conclusions of paragraph 2.4 are still valid and the main emphasis in the Residential sector is to upgrade of EPC Class for residential buildings, without completely ignoring the Cost-effective and Multi-benefit European market potential.

B. TYPICAL APPLICATIONS IN THE RESIDENTIAL SECTOR

B.1 EXTERNAL WALL HEAT-INSULATION AND VENTILATION HEAT RECOVERY

B.1.1 Assumptions

Let a typical residential building has an Area (A) 100 m^2, Length (L) = 12,0m, Width(W) = 8,5, Hight(H) = 3,4. Therefore side external wall = 2(L+W) =139 m^2 .

Window side area: 20%. Therefore, wall area is equal of 139. (80%) = 111,5 m^2.

Let the annual primary energy consumptions have as follows:

B.1.2 Calculations of heat losses

The heat demand due to wall heat transmission and ventilation is calculated through the Heating Degree Days (HDD) :

$$Q_{TV} = 24\frac{HDD}{1000}\left(\sum A_\nu U_\nu + (1-r)\frac{\dot{V}}{3}\right) - HG \text{ (in } kWh/m^2) \qquad (B.1)$$

Uν : Heat Transmission coefficient in W/(m^2.K), with original value of 0,8 for walls and 2,8 W/(m^2.K) for windows

Aν: Area of building element in m^2

$\dot{V}$: Ventilation air flow including air leakage in m^3/h, with a typical value in the Residential Sector V=0,75 m^3/h per m^2

r: Ventilation air heat recovery (%), originally equal to zero.

HG: Heat Gains (solar, internal) (kWh/m^2)

Applying the above values in equation 3.1 we get wall heat transmission Q_T and Ventilation loss Q_V: Q_T = 10.559 kWh and Q_V = 1560 kWh → Q_{TV} = Q_T+Q_V = 12911 kWh

Finally by using equation 3.1 (first half) we calculate heat transmission losses for the windows which are assumed to occupy the 20% of side external area: 0.02 x 139 = 27,9 m2 and with an initial heat transmission value of 2,8 W/(m2,K) the Q_W = 4871 kWh.

Therefore, the total heat losses are Q_{TOT} = Q_T + Q_V +Q_W = 16.990 kWh or 169,9 kWh/m^2. By dividing by 0,75 (heating system efficiency) the total heat primary energy requirements become: 22658 kWh or 226,6 kWh/m^2. /In all the above calculations, the heat gains were conservatively ignored.

B.1.3 Energy savings calculation by insulating walls and roof.

The new wall insulation has a thermal Transmission coefficient of U=0,25 W/(m^2.K). Therefore, the new heat transmission losses from the external wall are calculated as 3300 kWh and the energy savings at 10.559-3300 = 7260 kWh of 7260/16990 = 42,7%.

B.1.4 Energy savings by ventilation air with 85% heat recovery

By installing heat recovery ventilation modules in every room of the house, with 85% heat recovery, we gain additional savings of 1326 kWh. Therefore, the total fuel savings become:

(7260+1326)/16990 = 50.5%.

B.1.5Total investment and payback period

Investment

The wall insulation cost about 50 €/m2 i.e. 50 x 111,5 m2 = 6132 €

The ventilation modules are estimated to 500 € each, i.e. 3500 €

Total Investment € : 9632

Operational fuel savings of final energy (oil)

Energy charges for oil are estimated to 0,15 €/kWh, so for a total kWhs savings for heating from paragraphs 3.1.3 and 3.1.4 are equal to (7260+1326)/(0,75 x 1,1) = 10407 kWh where

1,1 is the conversion of primary energy to final energy.

0,75 is the total efficiency of the heating system

And total monetary savings become :1561 €. Therefore, the payback period results in 6,7 years.

B.1.6. The jump of EPC Classes

Originally

Assume the following energy uses: Hot Water: 30 kWh/m^2 (electricity): Rest electrical uses including lighting and air conditioning: 40 kWh/m^2,

From the above, Heating: 227 kWh/m2 (heating oil),

Therefore, total EP = 227 + 30+ 40 = 297 kWh/m^2 (paragraph 3.1.2)

This corresponds to EPC Class of E (Table A.5) with average consumption 289,4 kWh/m2

After new investment

With the new investments (wall heat insulation + ventilation heat recovery) heating energy savings of 50% are realized. Therefore, heating energy becomes 297/2 = 148,5 kWh/m^2 and the total EPC energy: 148,5+30+40 ~ 218,5 kWh/m^2

Comparing energy performances before and after the investment, energy savings are :

1 – 218,5/289,4 = 24,5%

These energy savings are not enough to cover the 44,3% as required by Table A.10 to reach Class C. Therefore, more energy saving investments are required to reach Class C, that is likely to be required by member states up to 2033.

B.2 BOILER REPLACEMENT WITH NEW CONDENSING BOILER

B.2.1 General

This investment is of paramount importance in fuel savings since it exhibits new efficiencies of the order to 98% including hot heating water circulation against 75% if the existing heating system's efficiency. The fuel selection would be natural gas if this fuel is now available, otherwise oil.

However, natural gas is only a transitory fuel only to hydrogen which is zero carbon fuel and is expected to be available to a large part of Europe by 2050, through the pipeline system of natural gas which is expected to be phased out by then and substituted by Hydrogen.

There is already in the market dual fuel condensing boilers capable to switch operation in both fuels. Anyway, whatever boiler replacement happens today, will certainly needs to be replaced much earlier than 2050, so any decision along these lines is not going to be detrimental.

B.2.2 Energy savings

The energy savings from boiler replacement with a condensing one are estimated as:

Fuel savings = 1 – η_{old}/η_{new} = 1 - 0,75/0,98 = 23,5%

With a total fuel consumption of:

Original

→ $Q_{TOT} = Q_{To}+Q_{Vo} + Q_{Wo}$ = 16.990 kWh (paragraph 3.1.2)

After wall insulation and heat recovery ventilation

$Q_{TOT} = Q_{Ta}+Q_{Va} + Q_{Wo}$ = 7260+(1560 – 1326) + 4871 = 12.365 kWh (paragraphs B.1.3 end B.1.4)

B.2.3 Energy Savings

Energy Savings: 12.365 (23,5%) = 4871 kWh

Percentage fuel savings: 4871/12.365 = 40%

Percentage primary energy savings: 4871/(12365 + 40 x100 + 30 x 100) = 4871/19365 = 25,1%

B.2.4. Payback period

Monetary savings: (4871 kWh) (0,15 €/kWh) /(1,1) = 664 €

Investment cost for 30 kW condensing boiler ~ 2500 €

Simple payback period : 2500/664 = 3,8 years

B.2.5. Total jump of EPC Classes

With a total energy savings of 25,1% from boiler replacement and 24,5% from the external wall insulation and ventilation heat recovery, the total energy savings from the original energy use is (1-24,5%).25,1%+24,5%= 43,5%. These energy savings are just about equal to cover the 44,6% as required by Table A.10 to reach EPC Class C from Class E.

B.2.6 Conclusions

The payback period for all these investments, which amount to 12500 €, is of the order of 5 to 6 years. For lower initial EPC classes (F, G) the investment requirements to reach Class C is expected to range from 15.000 € up to 20.000 € and payback periods of 6 to 9 years.

Therefore, the transition of low EPC Classes to C Class is expected to be done in a cost-effective way. Beyond that, the economic indices deteriorate significantly.

B.3 OTHER ENERGY EFFICIENCY INVESTMENTS

Besides the above three main investments:

- External wall thermal insulation
- Heat recovery ventilation
- Boiler replacement with condensing one

There is a number of other advanced energy savings investments which are very useful in further promote energy savings to higher EPC Classes, which among other include:

- Heat pumps geothermal of air source for heating and cooling
- Solar thermal systems for heating spaces and hot water, and cooling spaces coupled with absorption cooling techniques
- Control and automation systems for optimization of heating and cooling equipment.
- Passive solar heating techniques
- Biomass heating systems
- Industrial heat recovery and district heating systems
- Solar Photovoltaic renewable systems
- Biomass renewable cogeneration systems

- Hydrogen, renewables made, as a substitute for every fuel use

B.4 HEAT PUMPS

B.4.1 Primary Energy Savings (PES)

With a heating seasonal energy efficiency SCOP of 3,6 for air-source and for 4,5 to 5 for geothermal source heat pump may substitute any fuel with combustion efficiency of η, achieving significant primary energy savings.

Let Q be the final energy demand, and Pf and Pe are the primary energy conversion coefficients, taken prom standard ISO 520001-1:2015 : Pf = 1,1 for fuel. For electricity, Pe = 2,3 from convection electricity generation and Pe = 0,2.

I.e. for electricity system power by 40% renewables then: Pe = 60% x 2,3+40% x 0,2 = 1,46

Similarly and from ISO 52000, CO2 emission factors are taken Ef = 220 g/kWh for gasesous fuels and Ee= 420 gr/kWh for electricity.

Primary energy Consumption before, with boiler; *Pf.Q/η*.

Primary energy Consumption after, with a heat pump; *Pe.Q/SCOP*.

By dividing the above equations, primary energy savings (PES) are estimated as:

$$PES = 1 - \frac{Pe}{SCOP} \; / \; \frac{Pf}{\eta} = \text{1-(Pe.}\eta\text{)/(Pf.SCOP)=27,7\%} \qquad \text{(B.2)}$$

when Pf=1,1- Pe = 1,5- η= 0,75 and SCOP = 3,6.

B.4.2 Heat Pump Monetary Savings (MOS)

Heating

Applying the above equation 3.2 with instead the primary energy factors, the corresponding unit costs of energy, i.e. Mf = 0,15 €/kWh και Me = 0.25 €/kWh then MOS =

$$MOSH = 1 - \frac{Me}{SCOP} \; / \; \frac{Mf}{\eta} = \text{1-(Me.}\eta\text{)/(Mf.SCOP)= 65,3\%} \qquad \text{(B.3)}$$

Cooling

The new heat pump with a Seasonal Energy Efficiency Ratio (SEER) of 4,0 will replace the old heat pumps with SEERo = 2,5. Then the equation 3.3 becomes:

$$MOSC = 1 - \frac{Me}{SCOP} \; / \; \frac{Me}{\eta} = \text{1-(SEERo)/(SEER)= 37,5\%} \qquad \text{(B.4)}$$

Conclusion

Therefore, heat pump is highly energy efficiency and is capable to help jump at least on EPC Class up to 1,5 Class.

It is also highly economical if is used for both heating and cooling, exhibiting payback periods of 4 to 5 years.

B.5 OTHER APPLICATIONS

B.5.1 Solar thermal

Solar thermal technology has done a lot of significant steps and in now in a position to supply not only hot water but central heating water as well. It can achieve energy savings of the order:

- 60% and higher of domestic hot water
- 40 to 50% of central heating water for space heating.

Most of the time it is easier to find some roof space for solar collectors to caver at least the 60% of domestic hot water generation.

The combined solar systems (combi) may offer energy savings for up to one EPC Class jump, provided that there is access to solar lit areas. Payback periods range from 7 to 9 years.

Domestic hot water systems cost significantly lower and have much shorter payback periods.

B.5.2 Control and automation systems for optimization of heating and cooling equipment.

Automation and smart systems for energy savings, have been well established into EPBD methods. In the Annex A of EN standard EN 5232-1:2015 are given energy saving coefficients for various automation and control systems characterized by A (the best), B, C and D. which for the Residential sector have as follows:

Table B.1 Overall BAC(Building Automation and Controls) efficiency factors for Residential Buildings

Types of energy uses in the Residential Sector	D	C	B	A
	Non energy efficient	Reference standard	Advanced	High energy performance
For thermal energy $f_{BAC,th}$	1,10	1	0,88	0,81
For electrical energy $f_{BAC,el}$	1,08	1	0,9	0,92
For heating $f_{BAC,H}$	1,09	1	0,88	0,81
For cooling $f_{BAC,C}$	-	-	-	-
For domestic hot water $f_{BAC,DHW}$	1,11	1	0,9	0,8

The description of the above systems A, B, C, and D are given in EN 5232-1:2015 or other standards in the same series. Energy savings are calculated from this factors. For example for heating BAC jumping from C to A class, energy savings are estimate: = 1-0,81/1 = 19%

These savings are not trivial since they may help jump almost one EPC Class.